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SCIENTIFIC NOTES.

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This Circular is especially devoted to notes on recent scientific work by members of this University. It contains papers:

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PALÆONTOLOGY.

The Origin of the Oldest Fossils and the Discovery of the Bottom of the Ocean. By W. K. BROOKS.

(A paper read before the University Scientific Association, and printed in the Journal of Geology, Chicago, 1894.)

In the *Origin of Species* Darwin says that the sudden appearance of species belonging to several of the main divisions of the animal kingdom in the lowest known fossiliferous rocks, is at present inexplicable and may be truly urged as a valid objection to his views.

If his theory be true, he says that "it is indisputable that before the lowest Cambrian stratum was deposited long periods elapsed, as long as, or probably far longer than the whole interval from the Cambrian age to the present day; and that during these vast periods the world swarmed with living creatures. "Here," he says, "we encounter a formidable objection; for it seems doubtful whether the earth, in a fit state for the habitation of living creatures, has lasted long enough." "To the question why we do not find such fossiliferous deposits belonging to these assumed earliest periods prior to the Cambrian system I can give no satisfactory answer."

On its geological side this difficulty is even greater than it was in Darwin's day, for we now know that the fauna of the lower cambrian was rich and varied; that most of the modern types of animal life were represented in the oldest fauna which has been discovered, and that all its types have modern representatives. The palæontological side of the subject has been ably summed up by Walcott in an interesting memoir on the oldest fauna which is known to us from fossils, and his collection of 141 American species from the lower cambrian is distributed over most of the marine groups of the animal kingdom, and except for the absence of the remains of vertebrated animals, the whole province of animal life is almost as completely covered by these 141 species as it could be by a collection from the bottom of the modern ocean. Four of the American species are sponges, two are hydrozoa, nine are actinozoa, twenty-nine are brachiopods, three are lamellibranchs, thirteen are gasteropods, fifteen are pteropods, eight are crustacea, fifty-one are trilobites, and trails and burrows show the existence of at least six species of bottom forms, probably worms or crustacea. The most notable characteristic of this fauna is the completeness with which these few species outline the whole fauna of the modern sea floor. Far from showing us the simple unspecialized ancestors of modern animals, they are most intensely modern themselves in the zoölogical sense, and they belong to the same order of nature as that which prevails at the present day.

The fossiliferous beds of the lower cambrian rest upon beds which are miles in vertical thickness, and are identical in all their physical features with those which contain this fauna. They prove beyond question that the waters in which they were laid down were as fit for supporting life at the beginning as at the end of the enormous lapse of time which they represent, and that all the conditions have since been equally favorable for the preservation and the discovery of fossils. Modern discovery has brought the difficulty which Darwin points out into clearer view, but geologists are no more prepared than he was to give a satisfactory solution, although I shall now try to show that the study of living animals in their relations to the world around them does help us, and that comparative anatomy and comparative embryology and the study of the habits and affinities of organisms tell us of times more ancient than the oldest fossils, and give a more perfect record of the early history of life than palæontology.

While the history of life, as told by fossils, has been slow and gradual it has not been uniform, for we have evidence of the occurrence of several periods when modification was comparatively rapid.

We are living in a period of intellectual progress, and, among terrestrial animals, cunning now counts for more than size or strength, and fossils show that while the average size of mammals has diminished since the middle tertiary, the size of their brains has increased more than one hundred per cent.; that the brain of a modern mammal is more than twice as large, compared with its body, as the brain of its ancestors in the middle tertiary. Measured in years the middle tertiary is very remote, but it is

very modern compared with the whole history of the fossiliferous rocks, although more of brain development has been effected in this short time than in all preceding time from the beginning.

The later palæozoic and early secondary fossils mark another period of rapid change, when the fitness of the land for animal life, and the presence of land plants, brought about the evolution of terrestrial animals.

I shall give reasons for seeing, in the lower cambrian, another period of rapid change, when a new factor, the discovery of the bottom of the ocean, began to act in the modification of species, and I shall try to show that, while animal life was abundant long before, the evolution of animals likely to be preserved as fossils took place with comparative rapidity, and that the zoölogical features of the lower cambrian are of such a character as to indicate that it is a decided and unmistakable approximation to the primitive fauna of the bottom, beyond which life was represented only by minute and simple surface animals not likely to be preserved as fossils.

Nothing brings home more vividly to the zoölogist a picture of the diversity of the lower cambrian fauna, and of its intimate relation to the fauna on the bottom of the modern ocean, than the thought that he would have found on the old cambrian shore the same opportunity to study the embryology and anatomy of pteropods and gasteropods and lamellibranchs, of crustacea and medusæ, echinoderms and brachiopods that he now has at a marine laboratory; that his studies would have followed the same lines then that they do now, and that most of the record of the past which they make known to him would have been ancient history then. Most of the great types of animal life show by their embryology that they run back to simple and minute ancestors which lived at the surface of the ocean, and that the common meeting point must be projected back to a still more remote time, before these ancestors had become differentiated from each other.

After we have traced each great line of modern animals as far backwards as we can through the study of fossils, we still find these lines distinctly laid down. The lower cambrian crustacea, for example, are as distinct from the lower cambrian echinoderms or pteropods or lamellibranchs or brachiopods as they are from these of the present day, but zoölogy gives us evidence that the early steps in the establishment of these great lines were taken under conditions which were very different from those which have prevailed, without any essential change, from the time of the oldest fossils to the present day, and that most of the great lines of descent were represented in the remote past by ancestors which, living a different sort of life, differed essentially, in structure as well as in habits, from the representatives of the same types which are known to us as fossils.

In the echinoderms we have a well defined type represented by abundant fossils, very rich in living forms, very diversified in its modification and therefore well fitted for use as an illustration. This great stem contains many classes and orders, all constructed on the same plan, which is sharply isolated and quite unlike the plan of structure in any other group of animals. All through the series of fossiliferous rocks echinoderms are found, and their plan of structure is always the same. Palæontology give us most valuable evidence regarding the course of evolution within the limits of a class as in the crinoids or the echinoids; but we appeal to it in vain for light upon the organization of the primitive echinoderm, or for connecting links between the classes. To our questions on these subjects, and on the relation of the echinoderms to other animals, palæontology is silent, and throws them back upon us as unsolved riddles.

The zoölogist unhesitatingly projects his imagination, held in check only by the laws of scientific thought, into the dark period before the times of the oldest fossils, and he feels absolutely certain of the past existence of a stem, from which the classes of echinoderms have inherited the fundamental plan of their structure. He affirms with equal confidence that the structural changes which have separated this ancient type from the classes which we know from fossils, are very much more profound and extensive than all the changes which each class has undergone from the earliest palæozoic times to the present day.

He is also disposed to assume, but, as I shall show, with much less reason, that the amount of change which structure has undergone is an index to the length of time which the change has required, and that the period which is covered by the fossiliferous rocks is only an inconsiderable part of that which has been consumed in the evolution of the echinoderms.

The zoölogist does not check the flight of his scientific imagination here, however, for he trusts implicitly to the embryological evidence which teaches him that, still farther back in the past, all echinoderms were represented by a minute floating animal which was not an echinoderm at all in any sense except the ancestral one, although it was distinguished by features which natural selection has converted, under the influence of modern conditions, into the structure of echinoderms. He finds in the embryology of modern echinoderms phenomena which can bear no interpretation but this, and he unhesitatingly assumes that they are an inheritance which has been handed down from generation to generation through all the ages from the prehistoric times of zoölogy.

Other groups tell the same story with equal clearness. Lingula is still living in the sand bars and mud flats of the Chesapeake Bay, under conditions which have not effected any essential change in its structure since the time of the lower cambrian. Who can look at a living lingula without being overwhelmed by the effort to grasp its immeasurable antiquity; by the thought that while it has passed through all the chances and changes of geological history, the structure which fitted it for life on the earliest palæozoic bottom is still adapted for a life on the sands of the modern sea floor?

The everlasting hills are the type of venerable antiquity; but lingula has seen the continents grow up, and has maintained its integrity unmoved by the convulsions which have given the crust of the earth its present form.

As measured by the time-standards of the zoölogist lingula itself is modern, for its life-history still holds locked up in its embryology the record, repeated in the development of each individual, of a structure and a habit of life which were lost in the unknown past at the time of the lower cambrian, and it tells us vaguely but unmistakably of life at the surface of the primitive ocean, at a time when it was represented by minute and simple floating ancestors.

Broadly stated, the history of each great line has been like that of the echinoderms and brachiopods. The oldest pteropod or lamellibranch or echinoderm or crustacean or vertebrate which we know from fossils exhibits its own type of structure with perfect distinctness, and later influences have done no more than to expand and diversify the type, while anatomy fails to guide us back to the point where these various lines met each other in a common source, although it forces us to believe that the common source once had an individual existence. Embryology teaches that each line once had its own representative at the surface of the ocean, and that the early stages in its evolution have passed away and left no record in the rocks.

If we try to call before the mind a picture of the land surface of the earth we see a vast expanse of verdure, stretching from high up in the mountains over hills, valleys, and plains, and through forests and meadows down to the sea, with only an occasional lake or broad river to break its uniformity.

Our picture of the ocean is an empty waste, stretching on and on with no break in the monotony except now and then a flying fish or a wandering sea bird or a floating tuft of sargassum, and we never think of the ocean as the home of vegetable life. It contains plant-like animals in abundance, but these are true animals and not plants, although they are so like them in form and color. At Nassau, in the Bahama Islands, the visitor is taken in a small boat, with windows of plate-glass set in the bottom, to visit the "sea-gardens" at the inner end of a channel through which the pure water from the open sea flows between two coral islands into the lagoon. Here the true reef-corals grow in quiet water, where they may be visited and examined.

When illuminated by the vertical sun of the tropics and by the light which is reflected back from the white bottom, the pure transparent water is as clear as air, and the smallest object forty or fifty feet down is distinctly visible through the glass bottom of the boat.

As this glides over the great mushroom-shaped coral domes which arch up from the depths, the dark grottoes between them and the caves under their overhanging tops are lighted up by the sun, far down among the anthozoa or flower animals and the zoöphytes or animal plants, which are seen through the waving thicket of brown and purple sea fans and sea feathers as they toss before the swell from the open ocean.

There are miles of these "sea gardens" in the lagoons of the Bahamas, and it has been my good fortune to spend many months studying their wonders, but no description can convey any conception of their beauty and luxuriance.

The general effect is very garden-like, and the beautiful fishes of black and golden yellow and iridescent cobalt blue hover like birds among the thickets of yellow and lilac gorgonias.

The parrot fishes seem to be cropping the plants like rabbits, but more careful examination shows that they are biting off the tips of the gorgonias and branching madrepores or hunting for the small crustacea which hide in the thicket and that all the apparent plants are really animals.

The delicate star-like flowers are the vermillion heads of boring annelids or the scarlet tentacles of actinias, and the thicket is made up of pale lavender bushes of branching madrepores, and green and brown and yellow and olive masses of brain coral, of alcyonarians of all shades of yellow and purple, lilac and red, and of black and brown and red sponges. Even the lichens which incrust the rocks are hydroid corals, and the whole sea garden is a dense jungle of animals, where plant-life is represented only by a few calcareous algæ so strange in shape and texture that they are much less plant-like than the true animals.

The scarcity of plant-life becomes still more notable when we study the ocean as a whole. On land herbivorous animals are always much more abundant and prolific than the carnivora, as they must be to keep up the supply of food, but the animal life of the ocean shows a most remarkable difference, for marine animals are almost exclusively carnivorous.

The birds of the ocean, the terns, gulls, petrels, divers, cormorants, tropic birds and albatrosses, are very numerous indeed, and the only parallel to the pigeon roosts and rookeries of the land is found in the dense clouds of sea birds around their breeding grounds, but all these sea birds are carnivorous, and even the birds of the seashore subsist almost exclusively upon animals such as mollusca, crustacea and annelids.

The seals pursue and destroy fishes; the sea-elephants and walruses live upon molluscs; the whales, dolphins and porpoises and the marine reptiles all feed upon animals and most of them are fierce beasts of prey.

There are a few fishes which pasture in the fringe of seaweed which grows on the shore of the ocean, and there are some which browse among the floating tufts of algæ upon its surface, but most of them frequent these places in search of the small animals which hide among the plants.

In the Chesapeake Bay the sheepshead browses among the algæ upon the submerged rocks and piles like a marine sheep, but its food is exclusively animal, and I have lain upon the edge of a wharf watching it crunch the barnacles and young oysters until the juices of their bodies streamed out of the angles of its mouth and gathered a host of small fishes to snatch the fragments as they drifted away with the tide.

Many important fishes, like the cod, pasture on the bottom, but their pasturage consists of molluscs and annelids and crustacea instead of plants, and the vast majority of sea fishes are fierce hunters, pursuing and destroying smaller fishes, and often exhibiting an insatiable love of slaughter, like our own blue fish and the tropical albacore and barracuda. Others, such as the herring, feed upon smaller fishes and the pelagic pteropods and copepods; and others, like the shad, upon the minute organisms of the ocean, but all, with few exceptions, are carnivorous. In the other great groups of marine animals we find some scavengers, some which feed upon micro-organisms, and others which hunt and destroy each other, but there is no group of marine animals which corresponds to the herbivora and rodents and the plant-eating birds and insects of the land.

There is so much room in the vast spaces of the ocean, and so much of it is hidden, that it is only when surface animals are gathered together that the abundance of marine life becomes visible and impressive; but some faint conception of the boundless wealth of the ocean may be gained by observing the quickness with which marine animals become crowded together at the surface in favorable weather. On a cruise of more than two weeks along the edge of the gulf stream, I was surrounded continually night and day by a vast army of dark brown jelly-fish, (Linerges mercutia) whose dark color made them very conspicuous in the clear water. We could see them at a distance from the vessel, and at noon when the sun was over head we could look down to a great depth through the centre-board well, and everywhere, to a depth of fifty or sixty feet, we could see them drifting by in a steady procession, like motes in a sunbeam. We cruised through them for more than five hundred miles and we tacked back and forth over a breadth of almost a hundred miles, and found them everywhere in such abundance that there were some in every bucketful of water which we dipped up, nor is this abundance of life restricted to tropical waters, for Haeckel tells us that he met with such enormous masses of Limacina to the northwest of Scotland, that each bucket of water contained thousands.

The tendency to gather in crowds is not restricted to the smaller animals, and many species of raptorial fishes are found in densely packed banks.

The fishes in a school of mackerel are as numerous as the birds in a flight of wild pigeons, and we are told of one school which was a windrow of fish half a mile wide and at least twenty miles long. But while pigeons are plant eaters, the mackerel are rapacious hunters, pursuing and devouring the berrings as well as other animals.

Herring swarm like locusts, and a herring bank is almost a solid wall. In 1879 three hundred thousand river herring were landed in a single haul of the seine in Albemarle Sound; but the herring are also carnivorous, each one consuming myriads of copepods every day.

In spite of this destruction and the ravages of armies of medusæ and siphonophores and pteropods the fertility of the copepods is so great that they are abundant in all parts of the ocean, and they are met with in numbers which exceed our power of comprehension. On one occasion the "Challenger" steamed for two days through a dense cloud formed of a single species, and they are found in all latitudes from the arctic regions to the equator in masses which discolor the water for miles. We know, too, that they are not restricted to the surface, and that the banks of copepods are sometimes more than a mile thick. When we reflect that thousands would find ample room and food in a pint of water, one can form some faint conception of their universal abundance.

The organisms which are visible in the water of the ocean and on the sea bottom are almost universally engaged in devouring each other, and many of them, like the blue-fish, are never satisfied with slaughter, but kill for mere sport.

Insatiable rapacity must end in extermination unless there is some unfailing supply, and as we find no visible supply in the water of the ocean we must seek it with a microscope, which shows us a wonderful fauna made up of innumerable larvæ and embryos and small animals, but these things cannot be the food-supply of the ocean, for no carnivorous animal could subsist very long by devouring its own children. The total amount of these animals is inconsiderable, however, when compared with the abundance of a few forms of protozoa and protophytes, and both observation and deduction teach that the most important element in marine life consists of some half-dozen types of protozoa and unicellular plants: of globigerina and radiolarians, and of trichodesmium, pyrocystis, protococcus and the coccospheres, rhabdospheres and diatoms.

Modern microscopic research has shown that these simple plants, and the globigerinæ and radiolarians which feed upon them, are so abundant and prolific that they meet all demands and supply the food for all the animals of the ocean.

This is the fundamental conception of marine biology. The basis of all the life in the modern ocean is found in the micro-organisms of the surface.

This is not all. The simplicity and abundance of the microscopic forms and their importance in the economy of nature show that the organic world has gradually taken shape around them as its centre or starting-point, and has been controlled by them.

They are not only the fundamental food-supply but the primeval supply, which has determined the whole course of the evolution of marine life.

The pelagic plant-life of the ocean has retained its primitive simplicity on account of the very favorable character of its environment, and the higher rank of the littoral vegetation and that of the land is the result of hardship.

On land the mineral elements of plant-food are slowly supplied, as the rains dissolve them; limited space brings crowding and competition for this scanty supply; growth is arrested for a great part of each year by drought or cold; the diversity of the earth's surface demands diversity of structure and habit, and the great size and complicated structure of terrestrial plants are adaptations to these conditions of hardship.

At the surface of the ocean the abundance and uniform distribution of mineral food in solution; the area which is available for plants; the volume of sunlight and the uniformity of the temperature are all favorable to the growth of plants, and as each plant is bathed on all sides by a nutritive fluid, it is advantageous for the new plant-cells which are formed by cell-multiplication, to separate from each other as soon as possible, in order to expose the whole of their surface to the water. Cell-aggregation, the first step towards higher organization, is therefore disadvantageous to the pelagic plants, and as the environment at the surface of the ocean is so

monotonous, there is little opportunity for an aggregation of cells to gain any compensating advantage by seizing upon a more favorable habitat. The pelagic plants have retained their primitive simplicity, and the most distinctive peculiarity of the microscopic food-supply of the ocean is the very small number of forms which make up the enormous mass of individuals.

All the animals of the ocean are dependent upon this supply of microscopic food, and many of them are adapted for preying upon it directly, but a review of the animal kingdom will show that no highly organized animal has ever been evolved at the surface of the ocean although all depend upon the food-supply of the surface.

The animals which now find their home in the open waters of the ocean are, almost without exception, descendants of forms which lived upon or near the bottom, or along the sea-shore, or upon the land, and all the exceptions are simple animals of minute size. A review of the whole animal kingdom would take more space than we can spare, but it would show that the evidence from embryology, from comparative anatomy and from palæontology, all bears in the same direction and proves that every large and highly organized animal in the open ocean is descended from ancestors whose home was not open water but solid ground, either on the bottom or on the shore.

Embryology also gives us good ground for believing that all these animals are still more remotely descended from minute and simple pelagic ancestors, and that the history of all the highly organized inhabitants of the water has followed a roundabout path from the surface to the bottom and then back into the water.

When this fact is seen in all its bearings and its full significance is grasped, it is certainly one of the most notable and instructive features of evolution.

The food-supply of marine animals consists of a few species of microscopic organisms which are inexhaustible and the only source of food for all the inhabitants of the ocean. The supply is primeval as well as inexhaustible, and all the life of the ocean has gradually taken shape in direct dependence upon it.

In view of these facts we cannot but be profoundly impressed by the thought that all the highly organized marine animals are products of the bottom or the shore or the land, and that while the largest animals on earth are pelagic the few which are primitively pelagic are small and simple.

The reason is obvious. The conditions of life at the surface are so easy that there is little fierce competition, and the inorganic environment is so simple that there is little chance for diversity of habits.

The growth of terrestrial plants is limited by the scarcity of food, but there is no such limit to the growth of pelagic plants or the animals which feed on them, and while the balance of life is no doubt adjusted by competition for food this is never very fierce, even at the present day, when the ocean swarms with highly organized wanderers from the bottom and the shore. Even now the destruction or escape of a microscopic pelagic organism depends upon the accidental proximity or remotenesses of an enemy rather than upon defense or protection, and survival is determined by space relations rather than a struggle for existence.

The abundance of food is shown by the ease with which wanderers from the land, like sea birds, find places for themselves in the ocean, and the rapidity with which they spread over its whole extent.

As a marine animal the insect, Halobates, must be very modern as compared with most pelagic forms, yet it has spread over all tropical and subtropical seas, and it may always be found skimming over the surface of mid-ocean as much at home as a Gerris in a pond. I never found it absent in the Gulf Stream when conditions were favorable for collecting.

The easy character of pelagic life is shown by the fact that the larvæ of innumerable animals from the bottom and the shore have retained their pelagic habit, and I shall soon give reasons for believing that the larva of a shore animal is safer at sea than near the shore.

There was little opportunity in the primitive pelagic fauna and flora for an organism to gain superiority by seizing upon an advantageous site or by acquiring peculiar habits, for one place was like another, and peculiar habits could count for little in comparison with accidental space relations. After the fauna of the surface had been enriched by all the marine animals which have become secondarily adapted to pelagic life, competition with those improved forms brought about improvements in those which were strictly pelagic in origin, like the siphonophores, and those wanderers from the bottom introduced another factor into the evolution of pelagic life, for their bodies have been utilized for protection or concealment and in other ways, and we now have fishes which hide in the poison curtain of Physalia, crustacea which live in the pharynx of Salpa or in the mouth of the menhaden, barnacles and sucking fish fastened to whales and turtles, besides a host of external and internal parasites. The primitive ocean furnished no such opportunity, and the conditions of pelagic life must at first have been very simple, and while competition was not entirely absent the possibilities of evolution must have been extremely limited and the progress of divergent modification very slow so long as all life was restricted to the waters of the ocean.

There can be no doubt that floating life was abundant for a long period when the bottom was uninhabited. The slow geological changes by which the earth gradually assumed its present character present a boundless field for speculation, but there can be no doubt that the surface of the primeval ocean became fit for living things long before the deeper waters or the sea floor, and during this period the proper conditions for the production of large and complicated organisms did not exist, and even after the total amount of life had become very great it must have consisted of organisms of small size and simple structure.

Marine life is older than terrestrial life, and as all marine life has shaped itself in relation to the pelagic food supply, this itself is the only form of life which is independent, and it must therefore be the oldest. There must have been a long period in primeval times when there was a pelagic fauna and flora rich beyond limit in individuals, but made up of only a few simple types. During this time the pelagic ancestors of all the great groups of animals were slowly evolved, as well as other forms which have left no descendants. So long as life was restricted to the surface no great or rapid advancement, through the influences which now modify species, was possible, and we know of no other influences which might have replaced them. We are, therefore, forced to believe that the differentiation and improvement of the primitive flora and fauna was slow, and that, for a vast period of time, life consisted of an innumerable multitude of minute and simple pelagic organisms. During the time which it took to form the thick beds of older sedimentary rocks, the physical conditions of the ocean gradually took there present form, and during a part at least of this period the total amount of life in the ocean may have been very nearly as great as it is now without leaving any permanent record of its existence, for no rapid advance took place until the advantages of life on the bottom were discovered.

We must not think of the populating of the bottom as a physical problem, but as discovery and colonization, very much like the colonization of islands. Physical conditions for a long time made it impossible, but its initiation was the result of biological influences, and there is no reason why its starting-point should necessarily be the point where the physical obstacles first disappeared. It is useless to speculate upon the nature of the physical obstacles; there is reason to think one of them, probably an important one, was the deficiency of oxygen in deep water.

Whatever their character may have been they were all, no doubt, of such a nature that they first disappeared in the shallow water around the coast, but it is not probable that bottom life was first established in shallow water, or before the physical conditions had become favorable at considerable depths.

The sediment near the shore is destructive to most surface animals, and recent explorations have shown that a stratum of water of very great thickness is necessary for the complete development of the floating microscopic fauna and flora, and it is a mistake to picture them as confined to a thin surface stratum. Pelagic plants probably flourish as far down as light penetrates, and pelagic animals are abundant at very great depths. As the earliest bottom animals must have depended directly upon the floating organisms for food, it is not probable that they first established themselves in shallow water, where the food supply is both scanty and mixed with sediment; nor is it probable that their establishment was delayed until the great depths had become favorable to life.

The belts around elevated areas far enough from shore to be free from sediment, and deep enough to permit the pelagic fauna to reach its full development above them, are the most favorable spots, and palæontological evidence shows that they were seized upon very early in the history of life on the bottom.

It is probable that colony after colony was established on the bottom and afterwards swept away by geological change like a cloud before the wind,

and that the bottom fauna, which we know was not the first. Colonies which started in shallow water, were exposed to accidents from which those in great depths were free; and in view of our knowledge of the permanency of the sea-floor and of the broad outlines of the continents, it is now impossible that the first fauna which became established in the deep zone around the continents may have persisted and given rise to modern animals. However this may be, we must regard this deep zone as the birthplace of the fauna which has survived; as the ancestral home of all the improved metazoa.

The effect of life upon the bottom is more interesting than the place where it began, and we are now to consider its influence upon animals, all whose ancestors and competitors and enemies had previously been pelagic. The cold, dark, silent, quiet depths of the sea are monotonous compared with the land, but they introduced many new factors into the course of organic evolution.

It is doubtful whether the animals which first settled on the bottom secured any more food than floating ones, but they undoubtedly obtained it with less effort, and were able to devote their superfluous energy to growth and to multiplication, and thus to become larger and to increase in numbers faster than pelagic animals. Their sedentary life must have been favorable to both sexual and asexual multiplication, and the tendency to increase by budding must have been quickly rendered more active, and one of the first results of life on the bottom must have been to promote the tendency to form connected cormi, and to retain the connection between the parent and the bud until the latter was able to obtain its own food and to care for itself. The animals which first acquired the habit of resting on the bottom soon began to multiply faster than their swimming allies; and their asexually produced progeny, remaining for a longer time attached to and nourished by the parent stock, were much more favorably placed for rapid growth. As the animals of the bottom live on a surface, or at least a thin stratum, while swimming animals are distributed through solid space, the rapid multiplication of bottom animals must soon have led to crowding and to competition, and it quickly became harder and harder for new forms from the open water to force themselves in among the old ones, and colonization soon came to an end.

The great antiquity of all the types of structure which are represented among modern animals is therefore what we should expect, for after the foundation of the fauna of the bottom was laid it became, and has ever since remained, difficult for new forms to establish themselves.

Most of our knowledge of the sea bottom is from three sources: from dredgings and other explorations; from rocks which were formed beyond the immediate influence of continents, and from the patches of the bottom fauna which have gradually been brought near its surface by the growth of coral reefs, and from all these sources we have testimony to the density of the crowd of animals on favorable spots. Deep sea explorations give only the most scanty basis for a picture of the sea bottom, but they show that animal life may thrive with the dense luxuriance of tropical vegetation, and Sir Wyville Thomson says he once brought up at one time on a tangle which was fastened to a dredge over twenty thousand specimens of a single species of sea urchin. The number of remains of palæozoic crinoids and brachiopods and trilobites which are crowded into a single slab of fine grained limestone is most astounding, and it testifies most vividly and forcibly to the wealth of life on the old sea-floor.

No description can convey any adequate conception of the boundless luxuriance of a coral island, but nothing else gives such a vivid picture of the capacity of the sea-floor for supporting life. Marine plants are not abundant on coral islands and the animals depend either directly or indirectly upon the pelagic food-supply, so that their life is the same in this respect as that of animals in the deep sea far from land.

The abundant life is not restricted to the growing edge of the reef, and the inner lagoons are often like crowded aquaria. At Nassau my party of eight persons found so much to study on a little reef in a lagoon close to our laboratory that we discovered novelties every day for four months and our explorations seldom carried us beyond this little tract of bottom. Every inch of the bottom was carpeted with living animals, while others were darting about among the corals and gorgonias in all directions; but this was not all, for the solid rock was honeycombed everywhere by tubes and burrows, and when broken to pieces with a hammer each mass of coral gave us specimens of nearly every great group in the animal kingdom. Fishes, crustacea, annelids, mollusca, echinoderms, hydroids and sponges could be picked out of the fragments and the abundance of life inside the solid rock was most wonderful.

The absence of pelagic life in the landlocked water of coral islands is as impressive and noteworthy as the luxuriance of life upon and near the bottom.

On my first visit to the Bahama Islands I was sadly disappointed by the absence of pelagic animals where all the conditions seemed to be peculiarly favorable.

The deep ocean is so near that, as one cruises through the inner sounds past the openings between the islets which form the outer barrier, the deep blue water of mid-ocean is seen to meet the white sand of the beach, and soundings show that the outer edge is a precipice as high as the side of Chimborazo and much steeper.

Nowhere else in the world is the pure water of the deep sea found nearer land or more free from sediment, and on the days when the weather was favorable for outside collecting we found siphonophores and pteropods, pelagic molluscs and crustacea and tunicates and all sorts of pelagic larvæ in great abundance in the open water just outside the inlets.

Inside the barrier the water was always calm, and day after day it was as smooth as the surface of an inland lake. When I first entered one of these beautiful sounds, where the calm transparent water stretches as far as the eye can reach, while new beauties of islets and winding channels open before one as those which are passed fade away on the horizon, I felt sure that I had at last found a place where the pelagic fauna of mid-ocean could be gathered at our door and studied on shore. The water proved to be not only as pure as air but almost as empty. At high water we sometimes captured a few pelagic animals near the inlets, but we dragged our surface nets through the sounds day after day only to find them as clean as if they had been hung in the wind to dry. The water in which we washed them usually remained as pure and empty as if it had been filtered, and we often returned from our towing expeditions without even a copepod or a zoea or a pluteus.

The absence of the floating larvæ is most remarkable, for the sounds swarm with bottom animals which give birth every day to millions of swimming larvæ. The maugrove swamps and the rocky shores are fairly alive with crabs carrying eggs at all stages of development, and the boat passes over great black patches of sea-urchins crowded together by thousands. The number of animals engaged in laying their eggs or hatching their young is infinite, yet we rarely captured any larvæ in the tow net, and most of these we did find were well advanced and nearly through their larval life.

It is often said that the water of coral sounds is too full of lime to be inhabited by the animals of the open ocean, but this is a mistake, for the water is perfectly fit for supporting the most delicate and sensitive animals, and those which we caught outside lived in the house in water from the sounds better than in any other place where I ever tried to keep them, and instead of being injurious, the pure water of coral sounds is peculiarly favorable for use in aquaria for surface animals.

The scarcity of floating organisms can have only one explanation. They are eaten up, and competition for food is so fierce that nearly every organism which is swept in by the tide and nearly every larva which is born in the sounds is snatched by the tentacles around some hungry mouth.

Nothing could illustrate the fierceness of the struggle for food among the animals on a crowded sea-bottom more vividly than the emptiness of the water in coral sounds where the bottom is practically one enormous mouth. The only larvæ which have much chance to establish themselves for life are those which are so fortunate as to be swept out into the open ocean where they can complete their larval life under the milder competition of the pelagic fauna, and while it is usually stated that the larvæ of bottom animals have retained the pelagic habit for the purpose of distributing the species, it is more probable that it has been retained on account of its comparative safety.

These facts show that competition must have come quickly after the establishment of the first fauna on the bottom, and that it soon became very rigorous and led to severe selection and rapid modification; and we must also remember that life on the bottom brought with it many new opportunities for divergent specialization and improvement. The increase in size which came with economy of energy increased the possibilities of variation and led to the natural selection of peculiarities which improved the efficacy of the various parts of the body in their functions of relation to each other, and this has been an important factor in the evolution of complicated organisms.

The new mode of life also permitted the acquisition of protective shells, hard-supporting skeletons and other imperishable parts, and it is therefore probable that the history of evolution in later times gives no index as to the period which was required to evolve from small, simple pelagic ancestors the oldest animals which were likely to be preserved as fossils.

Life on the bottom also introduced another important evolutionary influence: competition between blood-relations. In those animals, which we know most intimately, divergent modification, with the extinction of connecting forms, results from the fact that the fiercest competitors of each animal are its closest allies, which, having the same habits, living upon the same food, and avoiding enemies in the same way, are constantly striving to hold exclusive possession of all that is essential to their welfare.

When a stock gives rise to two divergent branches, each escapes competition with the other so far as they differ in structure or habits, while the parent stock competing with both at a disadvantage is exterminated.

Among the animals which we know best, evolution leads to a branching tree-like genealogy with the topmost twigs represented by living animals while the rest of the tree is buried in the dead past. The connecting form between two species must therefore be sought in the records of the past or reconstructed by comparison.

Even at the present day things are somewhat different in the open ocean, and they must have been very different in the primitive ocean, for a pelagic animal has no fixed home, one locality is like another, and the competitors and enemies of each individual are determined in great part by accidents.

We accordingly find, even now, that the evolution of pelagic animals is often linear instead of divergent, and ancient forms, such as the sharks, often live on side by side with the later and more evolved forms. The radiolarians and medusæ and siphonophores furnish many well-known illustrations of this feature of pelagic life.

No naturalist is surprised to find in the South Pacific or in the Indian Ocean a salpa or a pelagic crustacean or a surface fish or a whale which was previously known only from the North Atlantic, and the list of species of marine animals which are found in all seas is a very long one. The fact that pelagic animals are so indepeudent of those laws of geographical distribution which limit land animals is additional evidence of the easy character of the conditions of pelagic life.

One of the first results of life on the bottom was to increase asexual multiplication and to lengthen the time during which buds remain united to and nourished by their parents, and to crowd individuals of the same species together and to cause competition between relations. We have in this and other obvious peculiarities of life on the bottom a sufficient explanation of the fact that since the first establishment of the bottom fauna, evolution has resulted in the elaboration and divergent specialization of the types of structure which were already established rather than the production of new types.

Another result of the struggle for existence on the bottom was the escape of varieties from competition with their allies by flight from the crowded spots and a return to the open water above; just as in later times the whales and sea birds have gone back from the land to the ocean.

These emigrants, like the civilized men who invade the homes of peaceful islanders, brought with them the improvements which had come from fierce competition, and they have carried everything before them and produced a great change in the pelagic fauna.

The rapid intellectual development which has taken place among the mammals since the middle tertiary, and the rapid structural changes which took place in animals and plants when the land fauna and flora were established, are well known, but the fact that the discovery of the bottom initiated a much earlier and probably more important era of rapid development in the forms of animal life has never been pointed out.

If this view is correct the primitive fauna of the bottom must have had the following characteristics: 1. It was entirely animal, without plants, and it at first depended directly upon the pelagic food supply.

2. It was established around elevated areas in water deep enough to be beyond the influence of the shore.

3. The great groups of animals were rapidly established from pelagic ancestors.

4. The animals of the bottom rapidly increased in size and hard parts were quickly acquired.

5. The bottom fauna soon produced progressive development among pelagic animals.

6. After the establishment of the fauna of the bottom elaboration and differentiation among the representatives of each primitive type soon set in and led to the extinction of connecting forms.

Many of the oldest fossils like the pteropods are the modified descendants of ancestors with hard parts, and there is no reason to suppose that the first animals which were capable of preservation as fossils have been discovered, but it is interesting to note that the oldest known fauna is an unmistakable approximation to the primitive fauna of the bottom.

The lower cambrian fossils are distributed through strata more than two miles thick, some, at least, of them showing by their fine grain and by the perfect preservation of tracks and burrows which were made in soft mud, and of soft animals like jelly fish, that they were deposited in water of considerable depth. The sediment was laid down slowly and gently in water so deep as to be free from disturbance and under conditions so favorable that it contains the remains of delicate animals not often found as fossils.

While the fauna of the lower cambrian undoubtedly lived in water of very considerable depth it was not oceanic but continental, for we are told by Walcott that "one of the most important conclusions is that the fauna of the lower Cambrian lived on the eastern and western shores of a continent that in its general configuration outlines the American continent of to-day." "Strictly speaking the fauna did not live upon the outer shore facing the ocean, but on the shores of interior seas, straits or lagoons that occupied the intervals between the several ridges that ran from the central platform east and west of the main continental land surface of the time."

This fauna was rich and varied, but it was not self-supporting, for no fossil plants are found, and the primary food supply was pelagic. Animals adapted for a rapacious life, such as the pteropods, were abundant, and prove the existence of a rich supply of pelagic animals. All the forms known from the fossils are either carnivorous, like the medusæ, corals, crustacea, and trilobites, or they are adapted, like the sponges, brachiopods, and lamellibranchs, for straining minute organisms out of the water or for gathering those which rain down from above, and the conditions under which they lived were very similar to those on the bottom at the present day.

Walcott's studies show that the earliest known fauna had the following characteristics: It consisted, so far as the record shows, of animals alone, and these were dependent upon the pelagic food supply for support. While small in comparison with many modern animals, they were gigantic compared with primitive pelagic animals. The species were few, but they represent a very wide range of types. All these types have modern representatives, and most of the modern types are represented in the lower cambrian. Their home was not the bottom of the deep ocean, but the shores of a continent under water of considerable depth.

The cambrian fauna is usually regarded as a half-way station in a series of animal forms which stretches backwards into the past for an immeasurable period, and it is even stated that the history of life before the cambrian is longer by many fold than its history since.

So far as this opinion rests on the diversity of types in cambrian times, it has no good basis; for if the views here advocated are correct the evolution of the ancestral stems took place at the surface, and all the conditions necessary for the rapid production of types were present when the bottom fauna first became established.

As we pass backwards towards the lower cambrian we find closer and closer agreement with the zoölogical conception of the character of primitive life on the bottom. While we cannot regard the oldest fauna which has been discovered as the first which existed on the bottom, we may feel confident that the first fauna of the bottom resembled that of the lower cambrian in its physical conditions and in its most distinctive peculiarities; the abundance of types, and the slight amount of differentiation among the representatives of these types; and we must regard it as a decided and unmistakable approximation to the beginning of the modern fauna of the earth, as distinguished from the more ancient and simple fauna of the open ocean.

CHEMISTRY.

A New Method for the Quantitative Determination of Nitrous Oxide. By GEO. T. KEMP.

PRELIMINARY COMMUNICATION.

The necessity for further research on the methods for the quantitative determination of nitrous oxide is readily seen from a brief review of the past work on the subject. The method most frequently employed is that recommended by Bunsen,[1] which consists in exploding with hydrogen, by which the nitrous oxide is reduced to water and nitrogen according to the equation

$$N_2O + H_2 = N_2 + H_2O.$$

The shrinkage in volume after the explosion is equal to the original volume of nitrous oxide present. This method has not met with general favor, as several observers have found the reaction not to be a clean one, side reactions giving rise to oxidation or reduction products, according to different conditions varying with the ratio of hydrogen to nitrous oxide and with pressure.

Frankland[2] refused to report positively on the question as to whether nitrous oxide was decomposed in the human body during anaesthesia, as he had no satisfactory method of determining the nitrous oxide in the inhaled and exhaled air. He says: "The separation of nitrogen and nitrous oxide presented quite unlooked-for obstacles, since their explosion with excess of hydrogen, instead of liberating free nitrogen from the nitrous oxide as commonly supposed, gives rise to the formation of nitrous acid and ammonia likewise." Using a large excess of hydrogen, and exploding under reduced pressure, gave better results, but "not so sharp as he could wish."[3]

Practically the same side reactions have been encountered by Goltstein, Winkler and Lunge. Goltstein[4] speaks of the method as "Höchst ungenau." Lunge[5] says that with hydrogen or oxyhydrogen side reactions, which render the results useless, readily take place.[6] Winkler[7] hoped to avoid the side reactions mentioned above by passing the gases over palladium asbestos, but though the decomposition into nitrogen and water took place readily, the results were not constant. A white cloud of ammonium nitrate or nitrite was sometimes seen. The method has been advocated by Dummreicher and by Hempel. Dummreicher,[8] apparently, was not acquainted with the adverse criticisms on the method, for he says that Bunsen's work was the only one with which he was familiar. He found that the method gave satisfactory results, and spoke of the reaction as smooth (glatt).

Hempel[9] also advocates explosion with hydrogen. Replying to Lunge's[10] article, which called attention to side reactions, he makes no criticism beyond saying that these were likely due to impurities in the gas. The purest gas which Hempel obtained from ammonium nitrate was 98 per ct. N_2O, and 2 per ct. N. He exploded this gas with hydrogen, in varying proportions alone, and with the admixture of oxyhydrogen gas. He finds the best mixture of hydrogen and nitrous oxide to be when $N_2O : H :: 1 : 2$ or 3. When oxyhydrogen gas is added it should be in such proportion that independent of the amount of nitrous oxide and hydrogen there shall be 26 to 64 volumes of oxyhydrogen gas to every 100 volumes of non-explosive gas.[11] He exploded with hydrogen when the ratio of H to N_2O was as low as 1.6 : 1, in which experiment the explosion was so violent as to break the apparatus, but he does not mention any side reactions. When $N_2O : H :: 1 : 4.6$, he found the mixture to be no longer explosive. He makes no mention of having tested his residual gas for ammonia after any of his explosions.

It may be of interest to add that Bunsen himself speaks of this, his method, as not being entirely satisfactory, but he does not speak of side reactions. In his Gasometrische Methoden he only gives one experiment, and as far as I can find, this is all he made.

[1] Bunsen, Gasometrische Methoden, 1878, p. 60.
[2] Transactions Odontological Society, Great Britain, 1872-73.
[3] Op. cit., p. 20.
[4] Goltstein, Arch. f. d. gesammt. Physiologie, 1878, p. 338.
[5] Lunge, Berichte, Vol. XIV, p. 2190.
[6] Bei der Verbrennung mit Wasserstoff oder Koallgas treten dann leicht unangenehme Nebenreactionen ein welche die Resultate unbrauchbar machen.
[7] Winkler, Industrie Gase, Vol. II, 1877, p. 427.
[8] Dummreicher, Monatsheft für Chemie, 1881, Vol. I, p. 732.
[9] Hempel, Berichte, 1882, Vol. XV, p. 903.
[10] Lunge, loc. cit.
[11] Op. cit., p. 910.

Several other methods for determining nitrous oxide have been suggested, but none are without objection; and a careful review of the literature has shown that only one of these methods has advocates besides the author who proposed it. This method is one proposed (for nitrous oxide) by Lunge,[1] and consists in absorbing the nitrous oxide by a considerable quantity of absolute alcohol, and allowing for the amount of other gases absorbed. Alcohol has a high coefficient of absorption for nitrous oxide in comparison to other gases. Lunge says the results by this method are always too high. For example, from a mixture containing 53.1 per ct. N_2O, he obtained 54.7 per ct. This method was used by Goltstein,[2] who found it superior to exploding with hydrogen, and, on the whole, satisfactory.

After finding that ammonia was formed in the reaction of nitrous oxide with hydrogen in the presence of an excess of hydrogen over platinum or palladinm asbestos, Winkler[3] suggests that a large excess of hydrogen be added, and that the gas be subjected for some time to the action of weakly heated platinum or palladium asbestos, claiming that the nitrogen of the nitrous oxide is, for the most part (der Hauptsache), transformed into ammonia. The ammonia is then determined by standard acid. He recommends this method in cases where the amount of nitrous oxide is very small.

Lunge[4] has tried this method, and criticizes it severely. He finds that a comparatively small amount of the nitrous oxide is converted into ammonia. Another method suggested by Winkler[5] is to pass nitrous oxide over a glowing palladium wire in a tube or in a grisoumeter. The nitrous oxide is split up according to the following reaction:

$$\underset{\text{2 vols.}}{2\ N_2O} = \underset{\text{3 vols.}}{2\ N_2} + O_2$$

so that the amount of nitrous oxide present is equal to twice the increase in volume. Winkler says of this method that it is the only one which has given really satisfactory results. Lunge has tried this, but says it is not quantitative. Moreover the decomposition is not a clean one, as various oxides of nitrogen are formed and the mercury is attacked. The presence of nitrogen peroxide, NO_2, was shown by the gas becoming brown.

The author of the present paper was led into the investigation, of which it is an account, by being confronted, in some pharmacological work on anaesthesia by nitrous oxide, with the problem of determining nitrous oxide in the presence of nitrogen, the total amount of gas being only 4 or 5 cc., and the nitrous oxide an unknown part of this, but likely as much as 80 or 90 per ct., thus leaving an exceedingly small residue of nitrogen.

Both Bunsen's method of exploding with hydrogen, and Winkler's method of decomposing the nitrous oxide over a hot palladium[6] wire were tried, but the results obtained were decidedly unsatisfactory. In working with nitrous oxide all the manipulation of the gas must be carried on over mercury, as water absorbs a considerable amount of the gas. In decomposing nitrous oxide with a glowing platinum wire, in a grisoumeter over mercury, the author's results were similar to those obtained by Lunge, viz: the gas became brown, showing the presence of nitrogen peroxide, NO_2, and though it might clear up, showing a possible decomposition of the NO_2 into nitrogen and oxygen, there was always a thick brown layer where the surface of the mercury had been attacked, thus binding the oxygen in a way which makes the method useless.

After a large number of determinations by exploding with hydrogen, I was forced to agree unequivocally with previous observers who found the method inaccurate because of side reactions. This could not be due to impurities in the nitrous oxide, for that was prepared by the method suggested by Dummreicher[7] of surrounding the retort, in which the ammonium nitrate is heated by a bath of molten metal of low fusing point. By taking this precaution to obtain uniform heating of the fused ammonium nitrate, and selecting clean well-formed crystals, the fused mass remained clear as water and the decomposition was a clean one, yielding N_2O about 100 per ct. pure, as shown by the analyses by the carbon monoxide method, which will be described later.

After exploding nitrous oxide with hydrogen in the Bunsen eudiometer in such proportions as to form an explosive mixture, and finding the results unsatisfactory, I was informed by Professor Orndorff, of Cornell University, of some unpublished experiments of Mr. B. S. Cushman, in the Cornell

[1] Lunge, op. cit., p. 2191.
[2] Arch. f. d. gesammt. Physiologie, 1878, p. 337.
[3] Op. cit., p. 429.
[4] Lunge, Berichte, XIV, p. 2191.
[5] Winkler, Industrie Gase, Vol. II, 1877, p. 260 and p. 426.
[6] In the author's experiments only platinum wire was used.
[7] Monatsheft f. Chemie, 1880, Vol. I, pp. 735, 741 and 742.

laboratory, in which he found that mixture of gases no longer explosive (*e. g.* oxygen and a large excess of hydrogen) could be smoothly burned out over a glowing platinum wire in a grisoumeter, the results being, if anything, more satisfactory than by explosion. Hoping that by avoiding the violent reaction of explosions, and using a larger amount of hydrogen, I might escape the side reactions, I made a series of combustions in the grisoumeter, and at first felt encouraged, for there was no evidence of the formation of the oxides of nitrogen or their acids in the presence of the large excess of hydrogen, and the mercury was not attacked.[1] The results were discordant, however—some coming out exactly, and some varying widely from 100 per ct. and from each other. In all experiments, but one, the reading was exact, or there was too much contraction after combustion. This persisted after extra precautions were taken to prevent the possible escape of hydrogen. The only explanation that suggested itself was the formation of ammonia, which, so far as I know, has never been tested for in such experiments. The test was made, after combustion, by bubbling the gas through ammonia-free water, in a Varentrap bulb, and treating this water with Nessler's solution. The results varied from a negative test to a deep yellow color, showing the formation of ammonia in varying amounts in the different experiments, which proves the method to be untrustworthy. Washing out the grisoumeter and testing the wash-water gives a better result than bubbling the residual gas through water and testing that. It seems that most of the ammonia is absorbed by the water formed in the reaction, which condenses on the surface of the mercury and on the glass. I was not able to find any factor that governed the formation of ammonia, unless it was true that the hotter the wire the greater was the tendency for its formation. Within the limit of the few seconds or minutes required for combustion, the time did not appear to have any effect. The addition of oxyhydrogen gas did not prevent the formation of ammonia. Two such experiments were made, in both of which ammonia was formed. The ratio of oxyhydrogen gas to the excess of hydrogen beyond that needed to unite with the oxygen of the nitrous oxide was as 8 to 100 in one case, and as 15 to 100 in the other. The explosions were quite violent, and I feared to add as much as Hempel recommended[2] (26-64 to 100), lest by breakage of the apparatus I should bring the work to a temporary standstill. These experiments differ from Hempel's, also, in being made in the grisoumeter over a glowing platinum spiral instead of with the spark, so that they are not in every respect comparable.

Since hydrogen gave such little promise of success, I tried various methods for reducing the nitrous oxide with carbon. The first method employed was to pass a series of electric sparks between specially constructed carbon electrodes. This decomposed the gas more rapidly than it reduced it. Carbon monoxide and carbon dioxide were formed, but oxides of nitrogen were formed at the same time. The mixture became brown and the mercury was attacked. The next method yielded better results. A piece of gas carbon was filed into a small cylinder about as thick as a match stick and about 6 mm. long. A platinum spiral was coiled around this and the whole introduced into the grisoumeter. Upon closing the circuit the spiral glowed and heated the carbon. In an atmosphere of nitrous oxide the carbon burned with great intensity, and reduced the nitrous oxide to CO and CO_2. Thinking that cyanogen might be formed in this reaction, as ammonia had been with hydrogen, I tested the residual gas in several experiments, but not a trace of cyanogen was found. I hoped by continuing the combustion to get all the gaseous carbon in the form of carbon monoxide, which would have doubled the volume of gas after combustion and halved the error of reading, thus:

$$\underset{\text{1 vol.}}{N_2O} + C = \underset{\text{2 vols.}}{N_2} + CO$$

This I found to be impossible, however, for even at the end of an hour's combustion there was a considerable amount of carbon dioxide present. To have determined the amount of nitrous oxide originally present, from the carbon monoxide and carbon dioxide formed in its reduction, would not have been as convenient as the next method tried, which proved to be both convenient and accurate. This method consisted in burning the nitrous oxide with a considerable excess of carbon monoxide in a grisoumeter and determining the CO_2 formed, from which the nitrous oxide could be calculated. Before I had taken up the grisoumeter work on hydrogen, Professor Morse suggested to try explosion with carbon monoxide. While working with Bunsen eudiometers I tried this, but found the results unsatisfactory. With a small excess of carbon monoxide, the explosion was violent; with a large excess the mixture would not explode, and in no case was the nitrous oxide completely reduced. Somewhat better though not satisfactory results were obtained by explosion in the grisoumeter later. Whether the difference is due to the different pressures in the two forms of apparatus I am unable to say, but it appears the most likely explanation. My own results in the experiments on nitrous oxide and hydrogen in the grisoumeter were quite in accord with the more extended observations of Cushman, already referred to, as to the ease and completeness with which non-explosive mixtures may be burned out over a glowing platinum spiral; so I determined to apply this method to the mixture of nitrous oxide and carbon monoxide, which had not yielded satisfactory results on explosion.

The grisoumeter usually employed for combustions over water[1] is not suitable for use with mercury, so that a proper form was improvised by using an ordinary Hempel pipette for solid reagents. To fit into the neck of this is chosen a rubber stopper with one hole. Through this hole is passed a piece of glass tubing, open at each end, but drawn out so as to form a shallow neck about 10 mm. from the end which extends into the grisoumeter. The lower end (below the stopper) is bent into a gentle curve, or an obtuse angle, for convenience of connection with a rubber tube. Into this glass tube, at any convenient point below the stopper, a piece of platinum wire is fused. The platinum spiral is made of fine wire, which is twisted, at each end, on to a piece of heavier platinum wire, so thick as not to be much heated by a current which will glow the spiral. The piece of stout wire connected with one end of the spiral is passed into the open end of the glass tube; the piece at the other end of the spiral is twisted two or three times around the constriction in the tube, for firmness, and the end then allowed to hang down beside the tube. The wire should be of sufficient length to reach to at least 40 mm. below the top of the tube, after having passed twice around the constricted neck. The spiral can now be fixed in any convenient position above the top of the tube by bending the stout wire. Connected with the lower end of the glass tube outside the grisoumeter is a piece of rubber tubing somewhat longer than the grisoumeter is high. To the free end of this is attached a funnel, by which the rubber and glass tube may be filled to the top with mercury. When so filled the rubber tube is closed, by a stout pinchcock, close to its connection with the glass tube. The funnel is supported by a separate stand. The platinum wire fused into the glass tube below the cork is thus connected, with the spiral, by the column of mercury in the tube, and when the mercury stands high enough in the grisoumeter to touch the platinum wire on the outside of the tube, the circuit can be closed through the spiral by connecting one pole of a battery with the platinum wire fused into the glass tube, while the other pole is connected with the mass of mercury filling the grisoumeter. This is best done by an iron wire passed straight down through the small bulb of the grisoumeter until it strikes the mercury.

The results of my experiments with this method are given in the following table. It must be borne in mind that the readings were all made in Hempel's burettes for technical gas analysis, and that these were not specially calibrated, so that the probable error is about $\pm .1$ cc.

Experiment.	Taken. cc.	Found. cc.	Ratio. $CO : N_2O$.
August 28, Burette 3...	9.8	9.8± .1	5.0 : 1
" 28, " 2...	9.7	9.7 "	6.4 : 1
" 29, " 1...	4.8	4.7+"	13.8 : 1
" 29, " 4...	3.3	3.5 "	21.0 : 1
" 30, " 3...	7.1	7.4 "	9.9 : 1
" 30, " 2...	5.5 +	5.7— "	18.4 : 1
" 31, " 1. ...	10.5	10.5 "	7.1 : 1
September 5, " 1...	4.8	5.2 "	17.7 : 1
" 5, " 2...	5.4	5.3 "	14.9 : 1
" 5, " 3...	12.4	12.2 "	6.2 : 1
" 5, " 4....	9.7	9.7 "	8.6 : 1
" 6, " 1...	10.2	10.3 "	7.1 : 1
" 6, " 3...	10.1	10.1 "	7.2 : 1
" 7, " 2...	17.2	17.3 "	4.5 : 1
" 7, " 1...	13.8	13.9 "	5.2 : 1

[1] In a few experiments an exception is noted, but always as doubtful and trifling in amount.

[2] Hempel, Berichte, 1882, p. 910.

[1] For description, see Hempel's Methods of Gas Analysis, translated by Dennts, Macmillan, 1892, p. 236.

The results are so grouped around 100 per ct. that the method is shown to be practically accurate—certainly for technical analysis. It will be noticed. however, that the tendency is to find more nitrous oxide than was taken; or in other words, the contraction after running the gas over potassium hydroxide was greater than it should have been. From some later work, an account of which will appear in the communication to follow, I have found that the presence of a fraction of a drop of water in the grisoumeter causes striking results. The water is vaporized by the heat of the glowing spiral, and a reaction takes place by which the water is decomposed, the oxygen uniting with the carbon monoxide to form carbon dioxide, and the hydrogen going free. This causes an increase in the volume of gas after combustion, which does not take place in the absence of an excess of water vapor above that which is necessary to saturate the gases. The reaction is probably expressed by the following:[1]

$$CO + H_2O = CO_2 + H_2.[2]$$

On running the gases over potassium hydroxide, the carbon dioxide formed in this reaction is absorbed with the carbon dioxide formed from the oxygen of the nitrous oxide; but in the reaction with the water, for every volume of carbon monoxide transformed into carbon dioxide, and thereby rendered absorbable, there is a volume of hydrogen left which exactly replaces it, so the result comes out even. The hydrogen set free in this reaction may possibly unite with the nitrogen set free by the reduction of the nitrous oxide, and ammonia may be formed as in the experiments with hydrogen; or, indeed, other condensation products may be formed. At the time these experiments were made I was not aware of this reaction between carbon monoxide and water, so that I did not note whether or not a fraction of a drop of water had gotten into the grisoumeter. In some experiments, however, I know this to have been the case, for after a partial combustion or an explosion I would run the gases over the potassium hydroxide, and after running them into the burette would then pass them back into the grisoumeter for a second combustion. In these instances I always got a small amount of the potassium hydroxide solution in the top of the capillary of the measuring burette, and sometimes a small particle of the liquid would be carried into the grisoumeter. I think it more than likely that working with a grisoumeter which thus contained an excess of moisture will account for the tendency for some results to come about .1 cc. or more too high, while hardly any fall below.

One very great advantage of this method is that when the amount of nitrous oxide is small, it may be diluted with a large amount of carbon monoxide for convenience of manipulation, and still give good results from combustion. The most satisfactory results and the smoothest and quickest reaction is obtained when approximately, $CO : N_2O :: 7 : 1$. If there is less carbon monoxide the mixture explodes, and when the excess of carbon monoxide is large it takes a longer time for complete combustion. It is always best to give a combustion of at least 3 to 5 minutes. Unless excess of moisture be present there are no side reactions, and no evidence of condensation products even after a combustion of an hour.

The experiments, referred to in the present communication, were carried on in the Hoagland Laboratory of Brooklyn, and at the Physiological Laboratory of the Johns Hopkins University during my connection with those laboratories. In addition to this, through the courtesy of Professor Morse, I was able to avail myself of the facilities of the Chemical Laboratory of the Johns Hopkins University, and through the courtesy of Professors Dennis and Orndorff of Cornell University, I was invited to make use of the facilities of their laboratories while spending my vacation at Ithaca. It was there that the work was brought to a successful termination. It gives me pleasure to express my obligation to these gentlemen for the said courtesies, as well as for useful suggestions from time to time. I am also indebted to Mr. B. S. Cushman, of Cornell, for much valuable assistance.

[1] Dixon, Phil. Trans., 1884, and Journ. Chem. Society, 1886.

[2] In my own experiments I have shown the presence of free hydrogen by absorption with palladium.

ASTRONOMICAL NOTES.

The following notes of work in Astronomy were collected and edited by Dr. CHARLES LANE POOR, Associate in Astronomy.

Special Perturbations due to the Elliptic Figure of a Planet. By CHARLES LANE POOR.

I recently investigated the disturbances in the motion of a comet caused by the ellipticity of Jupiter. Such disturbances, of course, will become appreciable only when the comet is in the immediate vicinity of the planet. The results of this investigation were published in the Astronomical Journal, the complete formulas used, however, were not given. As they are for the most part new, I insert them here. They give the perturbations of the elements of the relative orbit about the planet.

The differential coefficients for the variation of the elements may be computed by the usual formulas. The component disturbing forces, R, S, and Z, can be computed as follows:

La Place in the Mécanique Céleste expresses that part of the perturbative function, which depends upon the ellipticity of Jupiter, in the following form,

$$\tfrac{1}{3}\,(\rho - \tfrac{1}{2}\,\phi)\,(1 - 3\sin^2\delta)\,\frac{mB^2}{r^2} \qquad (1)$$

where the factor $(\rho - \frac{1}{2}\,\phi)$ depends upon the shape and the speed of rotation of the planet; B is the equatorial radius of the planet, and r and δ are respectively the radius vector and the jovian declination of the disturbed body. From investigations on the motions of the satellites the value of the first factor was found by La Place,

$$\log\,(\rho - \tfrac{1}{2}\,\phi) = 8.34047 \qquad (2)$$

From (1) we find by differentiation the expressions for the disturbing forces in the directions of r and δ; and thence by resolving the latter into its components, the required forces, R, S, and Z. The formulas for this latter step are rather complicated, unless we first refer the elements of the comet's orbit to Jupiter's equator as fundamental plane, or else neglect the inclination of this latter to the ecliptic. As this inclination is but 3° we may neglect it in a first approximation. The formulas, as thus deduced, are; β being an auxiliary angle;—

$$\operatorname{Cot}\beta = \cos u \tan i$$
$$\sin\delta = \sin u \sin i$$
$$R_o' = -\,(1 - 3\sin^2\delta)\,\frac{1}{r^4}$$
$$S_o' = -\sin 2\,\delta \cos\beta\,\frac{1}{r^4}$$
$$Z_o' = -\sin 2\,\delta \sin\beta\,\frac{1}{r^4}$$

and,

$$R = R_o'.\,\frac{\omega\, m\, B^2}{\sqrt{p}}\,(\rho - \tfrac{1}{2}\,\phi)$$
$$S = S_o'.\,\frac{\omega\, m\, B^2}{\sqrt{p}}\,(\rho - \tfrac{1}{2}\,\phi)$$
$$Z = Z_o'.\,\frac{\omega\, m\, B^2}{\sqrt{p}}\,(\rho - \tfrac{1}{2}\,\phi)$$

The disturbing forces are, therefore, proportional to the inverse fourth power of the radius vector, and hence, for a close approach, the resulting perturbations may become very large.

Formulas for Computing the Perturbations of Hyperbolic Elements. By CHARLES LANE POOR.

In an investigation, lately completed, it became necessary for me to compute the perturbations suffered by a comet, whilst it was traveling a hyperbolic orbit. For many reasons I could not conveniently use the usual methods of computing the perturbations of rectangular coördinates, and it therefore became necessary to deduce the requisite formulas for directly

computing the perturbations of the hyperbolic elements. As I believe that such formulas have never appeared in print, and as they may be of use to others working in similar lines, I append them in their final shape.

The quantities, of which the perturbations are found, are as follows:— the four elements, π, Ω, i, and e, and the two auxiliaries, ν and N; Watson's notation being used throughout. The component disturbing forces, R, S, and Z, are computed by the usual formulas, but are expressed in radians and in units of the sixth decimal place.

For the sake of convenience the following well known formulas and definitions are first given:

a, the semi-axis major, always taken as positive in the formulas.

v, the true anomaly.

u, the argument of latitude.

λ, the modulus of common logarithms.

ψ, ν, N, and F, are auxiliary quantities in the hyperbola, analogous to the quantities ϕ, μ, M, and E, in an elliptic orbit, and are given by the equations:—

$$\cos\psi = \frac{1}{e}$$
$$\nu = \frac{\lambda k}{a^{\frac{3}{2}}}$$
$$N = \nu\,(t - T)$$
$$e\lambda \tan F = N + \log\tan\,(45^\circ + \tfrac{1}{2}F).$$

The formulas for the differential coefficients of the elements are then as follows, where ω is the number of days interval between the computations, and the quantities in brackets are logarithms:

$$(i:\ Z) = r\cos u\ [9.31442]$$
$$(\Omega:\ Z) = \frac{r\sin u}{\sin i}\ [9.31442]$$

$$(\pi:\ R) = -\frac{p\cos v}{e}\ [9.31442]$$
$$(\pi:\ S) = (p + r)\frac{\sin v}{e}\ [9.31442]$$
$$(\pi:\ Z) = r\sin u\tan\tfrac{1}{2}i\ [9.31442]$$

$$(\nu:\ R) = 3\nu a\omega.\ e\sin v$$
$$(\nu:\ S) = 3\nu a\omega.\ \frac{p}{r}$$

$$(e:\ R) = p\sin v$$
$$(e:\ S) = p\cos v + \frac{p}{\cos F}$$

$$(N:\ \nu) = \frac{2\lambda r}{3\nu a}\frac{\sin\psi}{\sin v}$$
$$(N:\ e) = -\lambda\sin\psi\cot v.$$

From these coefficients the variations of the elements are found in the usual manner by multiplying each by the corresponding disturbing force, as in the following:—

$$\omega\frac{d\pi}{dt} = (\pi:R)\,R + (\pi:S)\,S + (\pi:Z)\,Z.$$
$$\omega\frac{dN}{dt} = (N:\nu)\,\omega\frac{d\nu}{dt} + (N:e)\,\omega\frac{de}{dt},$$
etc., etc.

And from these the total change in the elements from one period to another may be found by simple mechanical quadrature.

On the Expression of Bessel's Functions in Form of Definite Integrals. By A. S. Chessin.

Let us consider first Bessel's function of the zeroth order,

$$(1)\qquad J_0(x) = \sum_{n=0}^{n=\infty}\frac{(-1)^n a^{2n}}{(n!)^2},$$

where $a = \frac{x}{2}$. A well known formula of Cauchy,

$$(2)\qquad \frac{f^n(a)}{n!} = \frac{1}{2\pi i}\int_R \frac{f(z)}{(z-a)^{n+1}}\,dz,$$

will give us the means of expressing $J_0(x)$ in form of a definite integral. The integration in (2) is taken along a circle (R), within the region of which the function $f(z)$ is holomorphic, the point a being the centre of this circle. We can take $f(z) = e^{-a^2 z}$ and $a = 0$. Then $f^n(0) = (-1)^n a^{2n}$ and

$$(2)'\qquad \frac{(-1)^n a^{2n}}{n!} = \frac{1}{2\pi i}\int_R \frac{e^{-a^2 z}}{z^{n+1}}\,dz.$$

Multiplying (2)′ by $n!$ and applying the $\sum_{n=0}^{n=\infty}$ to the result, we find

$$(3)\qquad \sum_{n=0}^{n=\infty}\frac{(-1)^n a^{2n}}{(n!)^2} = J_0(x) = \frac{1}{2\pi i}\int_R \sum_{n=0}^{n=\infty}\frac{e^{-a^2 z}}{n!\,z^{n+1}}\,dr = \frac{1}{2\pi i}\int_R \frac{e^{-a^2 z + \frac{1}{z}}}{z}\,dz.$$

The integral being taken along the circle (R), let

$$z = R\,(\cos\theta + i\sin\theta)$$

Then

$$\frac{1}{2\pi i}\int_R \frac{e^{-a^2 z + \frac{1}{z}}}{z}\,dz = \frac{1}{2\pi}\int_0^{2\pi} e^{\lambda\cos\theta}\cos(\mu\sin\theta)\,d\theta - \frac{i}{2\pi}\int_0^{2\pi} e^{\lambda\cos\theta}\sin(\mu\sin\theta)\,d\theta$$

where

$$(4)\qquad \begin{cases}\lambda = \dfrac{1}{R} - a^2 R\\ \mu = \dfrac{1}{R} + a^2 R\end{cases}$$

But, as is easily verified,

$$\int_0^{2\pi} e^{\lambda\cos\theta}\sin(\mu\sin\theta)\,d\theta = 0$$

hence

$$(5)\qquad J_0(x) = \frac{1}{2\pi}\int_0^{2\pi} e^{\lambda\cos\theta}\cos(\mu\sin\theta)\,d\theta.$$

In this expression is involved an arbitrary element, namely, the radius R.

If we choose it so, that $\lambda = 0$, that is $R = \left|\frac{1}{a}\right|$, formula (5) takes the well known form

$$(6)\qquad J_0(x) = \frac{1}{2\pi}\int_0^{2\pi}\cos(\mu\sin\theta) = \frac{2}{\pi}\int_0^{\frac{\pi}{2}}\cos(x\sin\theta)\,d\theta.$$

Let us now consider the Besselian function $J_n(x)$ of the n^{th} order, n being an integer number. As is well known, only positive values of n need to be considered, owing to the relation

$$J_n(x) = (-1)^n J_{-n}(x).$$

By definition,

$$(7)\qquad J_n(x) = a^n\sum_{\kappa=0}^{\kappa=\infty}\frac{(-1)^\kappa a^{2\kappa}}{\kappa!\,(n+\kappa)!}.$$

Using again Cauchy's formula (2),

$$\sum_{\kappa=0}^{\kappa=\infty}\frac{(-1)^\kappa a^{2\kappa}}{\kappa!\,(n+\kappa)!} = \frac{1}{2\pi i}\int_R\sum_{\kappa=0}^{\kappa=\infty}\frac{e^{-a^2 z}}{(n+\kappa)!\,z^{\kappa+1}}\,dz$$
$$= \frac{1}{2\pi i}\int_R z^{n-1}e^{-a^2 z}\left(e^{\frac{1}{z}} - \sum_{m=0}^{m=n-1}\frac{1}{m!\,z^m}\right)dz = \frac{1}{2\pi i}\int_R z^{n-1}e^{-a^2 z + \frac{1}{z}}\,dz - \frac{1}{2\pi i}\sum_{m=0}^{m=n-1}\frac{1}{m!}\int_R e^{-a^2 z}z^{n-m-1}\,dz.$$

But $\int_R e^{-a^2 z}z^{n-m-1}\,dz$ vanishes for all the values of m, from 0 to $n-1$, as an integral $\int f(z)\,dz$, taken along a closed contour, vanishes when $f(z)$ is holomorphic within its region. Hence

$$(8)\qquad a^n\sum_{\kappa=0}^{\kappa=\infty}\frac{(-1)^\kappa a^{2\kappa}}{\kappa!\,(n+\kappa)!} = J_n(x) = \frac{a^n}{2\pi i}\int_R z^{n-1}e^{-a^2 z + \frac{1}{z}}\,dz.$$

If we put again $z = R(\cos\theta + i\sin\theta)$, we find

$$(9)\quad J_n(x) = \frac{(Ra)^n}{2\pi}\int_0^{2\pi} e^{\lambda\cos\theta}\cos(n\theta - \mu\sin\theta)\,d\theta + i\,\frac{(Ra)^n}{2\pi}\int_0^{2\pi} e^{\lambda\cos\theta}\sin(n\theta - \mu\sin\theta)\,d\theta,$$

where again,

$$(10)\quad \begin{cases}\lambda = \dfrac{1}{R} - a^2R\\ \mu = \dfrac{1}{R} + a^2R.\end{cases}$$

Again, it can be easily verified, that

$$\int_0^{2\pi} e^{\lambda\cos\theta}\sin(n\theta - \mu\sin\theta)\,d\theta = 0,$$

so that

$$(11)\quad J_n(x) = \frac{(Ra)^n}{2\pi}\int_0^{2\pi} e^{\lambda\cos\theta}\cos(n\theta - \mu\sin\theta)\,d\theta = \frac{(Ra)^n}{\pi}\int_0^{\pi} e^{\lambda\cos\theta}\cos(n\theta - \mu\sin\theta)\,d\theta.$$

This expression again involves an arbitrary element, namely R. If we choose R so that $\lambda = 0$, *i. e.*,

$$R = \left|\frac{1}{a}\right|,$$

we shall have

$$(11)'\quad J_n(x) = \frac{(\pm 1)^n}{\pi}\int_0^{\pi}\cos(n\theta \mp x\sin\theta)\,d\theta.$$

The upper or lower indices are to be taken simultaneously before the integral and before z. But, as is easily shown,

$$(-1)^n\int_0^{\pi}\cos(n\theta + x\sin\theta)\,d\theta = \int_0^{\pi}\cos(n\theta - x\sin\theta)\,d\theta,$$

so that suffices to take the upper sign in (11)′. Then

$$(12)\quad J_n(x) = \frac{1}{\pi}\int_0^{\pi}\cos(n\theta - x\sin\theta)\,d\theta$$

which is a well known expression.

If we put $n = 0$ in (12) we obtain again the expression (6).

On Poisson's Coefficients (a_i, a_j) for the Planetary Motion. By A. S. CHESSIN.

It is usual to derive the expressions for these coefficients indirectly by means of Lagrange's coefficients $[a_i, a_j]$. I will show in this note a way of forming Poisson's coefficients directly, which is more simple than the one commonly used. To this purpose I will first write down the six *integrals* of the elliptic motion. In order to simplify the formulas, the following notations will be used:

r for $\sqrt{x^2+y^2+z^2}$
v " $\sqrt{x'^2+y'^2+z'^2}$
c_1 " $yz' - zy'$
c_2 " $zx' - xz'$
c_3 " $xy' - yx'$
c " $\sqrt{c_1^2+c_2^2+c_3^2}$
μ " $M + m$.

Then the six integrals can be presented in the following form:

$$(1)\quad a = \frac{\mu r}{2\mu - rv^2}$$

$$(2)\quad e = \sqrt{1 - \frac{c^2}{\mu a}}$$

$$(3)\quad \omega = -tn^{-1}\left(\frac{c_1}{c_2}\right)$$

$$(4)\quad i = \cos^{-1}\left(\frac{c_3}{c}\right)$$

$$(5)\quad \pi = \omega + \sin^{-1}\left(\frac{z}{r\sin i}\right) - \sin^{-1}\left(\frac{cr'}{\mu e}\right)$$

$$(6)\quad \epsilon = \pi - n\tau,$$

where

$$(7)\quad -n\tau = -nt - \frac{rr'}{na^2} + \sin^{-1}\left(\frac{rr'}{nea^2}\right).$$

In (2) a is supposed to be expressed by means of (1); in (5), ω, i, e are supposed to be expressed by means of (3), (4), (2), and so on. Formulas (1)-(7) are readily obtained from the well known formulas of the elliptic motion.

As the coefficients (a_i, a_j) *are independent of* t, a considerable simplification will be obtained by choosing the moment $t = \tau$ of passage through the perihelion. However, this substitution is to be made only *after* the expressions of the (a_i, a_j) had been formed.

I will begin by forming the symbols (c_1, a_i), (c_2, a_i), (c_3, a_i), (c, a_i). We easily find:

$$(8)_1\quad (c_1, a_i) = \left(z'\frac{\partial a_i}{\partial y'} - y'\frac{\partial a_i}{\partial z'}\right) + \left(z\frac{\partial a_i}{\partial y} - y\frac{\partial a_i}{\partial z}\right)$$

$$(8)_2\quad (c_2, a_i) = \left(x'\frac{\partial a_i}{\partial z'} - z'\frac{\partial a_i}{\partial x'}\right) + \left(x\frac{\partial a_i}{\partial z} - z\frac{\partial a_i}{\partial x}\right)$$

$$(8)_3\quad (c_3, a_i) = \left(y'\frac{\partial a_i}{\partial x'} - x'\frac{\partial a_i}{\partial y'}\right) + \left(y\frac{\partial a_i}{\partial x} - x\frac{\partial a_i}{\partial y}\right)$$

$$(8)\quad (c, a_i) = \frac{1}{c}\left\{c_1(c_1, a_i) + c_2(c_2, a_i) + c_3(c_3, a_i)\right\} = \frac{v^2}{c}\left(x\frac{\partial a_i}{\partial x'} + y\frac{\partial a_i}{\partial y'} + z\frac{\partial a_i}{\partial z'}\right) - \frac{r^2}{c}\left(x'\frac{\partial a_i}{\partial x} + y'\frac{\partial a_i}{\partial y} + z'\frac{\partial a_i}{\partial z}\right).$$

We also shall need the following formulas:

$$(9)\quad (r, a_i) = \frac{1}{r}\left(x\frac{\partial a_i}{\partial x'} + y\frac{\partial a_i}{\partial y'} + z\frac{\partial a_i}{\partial z'}\right)$$

$$(10)\quad (r', a_i) = \frac{1}{r}\left(x'\frac{\partial a_i}{\partial x'} + y'\frac{\partial a_i}{\partial y'} + z'\frac{\partial a_i}{\partial z'}\right) - \frac{1}{r}\left(x\frac{\partial a_i}{\partial x} + y\frac{\partial a_i}{\partial y} + z\frac{\partial a_i}{\partial z}\right)$$

$$(11)\quad (z, a_i) = \frac{\partial a_i}{\partial z'}.$$

We see at once, from (3), (4) and (10), that ω and i being homogenous functions of the same order of x, y, z and x', y', z', we shall have

$$(12)\quad (r', \omega) = (r', i) = 0.$$

From (1) we find:

$$(I)\quad \begin{aligned}&\frac{\partial a}{\partial x} = f_1x \qquad \frac{\partial a}{\partial x'} = f_2x'\\ &\frac{\partial a}{\partial y} = f_1y \qquad \frac{\partial a}{\partial y'} = f_2y' \qquad f_1 = \frac{2a^2}{r^3};\quad f_2 = \frac{2a^2}{\mu}\\ &\frac{\partial a}{\partial z} = f_1z \qquad \frac{\partial a}{\partial z'} = f_2z'.\end{aligned}$$

Then the substitution of a for a_i into formulas $(8)_1$-(8) and (9)-(11) gives:

$$(13)\quad (c_1, a) = (c_2, a) = (c_3, a) = (c, a) = 0$$

$$(14)\quad (r, a) = f_2r' = 0$$

$$(15)\quad (r', a) = \frac{1}{r}(f_2v^2 - f_1r^2) = -\frac{2ea^2}{r^2}$$

$$(16)\quad (z, a) = f_2z' = \frac{2a^2z'}{\mu}.$$

From (3) we find:

$$(III)\quad \begin{aligned}&\frac{\partial\omega}{\partial x} = c_1f_3 \qquad \frac{\partial\omega}{\partial x'} = c_1f_4\\ &\frac{\partial\omega}{\partial y} = c_2f_3 \qquad \frac{\partial\omega}{\partial y'} = c_2f_4 \qquad f_3 = -\frac{z'}{c^2\sin^2 i};\quad f_4 = \frac{z}{c^2\sin^2 i}\\ &\frac{\partial\omega}{\partial z} = c_3f_3 \qquad \frac{\partial\omega}{\partial z'} = c_3f_4.\end{aligned}$$

Substituting ω for a_i into formulas $(8)_3$ (8) and (9)-(11), we obtain:

$$(17)\quad (c_3, \omega) = -f_4z'v^2 + f_3z'r^2 = -\frac{z^2v^2 + z'^2r^2}{c^2\sin^2 i} = -\frac{c_1^2 + c_2^2}{c^2\sin^2 i} = -1$$

$$(18)\quad (c, \omega) = \frac{v^2}{c}f_4(c_1x + c_2y + c_3z) - \frac{r^2}{c}f_3(c_1x' + c_2y' + c_3z') = 0$$

$$(19)\quad (r, \omega) = 0$$

$$(20)\quad (z, \omega) = f_4c_3 = \frac{z\cos i}{c\sin^2 i}.$$

From (4) we find:

$$\frac{\partial i}{\partial x} = c_1 f_b \qquad \frac{\partial i}{\partial x'} = c_1 f_e$$

(IV) $$\frac{\partial i}{\partial y} = c_2 f_b \qquad \frac{\partial i}{\partial y'} = c_2 f_e \qquad f_b = \frac{z v^2}{c^2 \sin i}, \quad f_e = \frac{z' r^2}{c^2 \sin i}$$

$$\frac{\partial i}{\partial z} = c_3 f_b \qquad \frac{\partial i}{\partial z'} = c_3 f_e.$$

Then are obtained:

(21) $$(c, i) = 0.$$

(22) $$(r, i) = 0.$$

(23) $$(z, i) = c_3 f_e = \frac{z' r^2 \cos i}{c^2 \sin i}.$$

We will now form the symbols for a, ω, e, i.

1. $$(a, \omega) = \frac{\partial \omega}{\partial c_1}(a, c_1) + \frac{\partial \omega}{\partial c_2}(a, c_2) = 0.$$

2. $$(a, e) = \frac{\partial e}{\partial c}(a, c) + \frac{\partial e}{\partial a}(a, a) = 0.$$

3. $$(a, i) = \frac{\partial i}{\partial c_3}(a, c_3) + \frac{\partial i}{\partial c}(a, c) = 0.$$

4. $$(\omega, e) = \frac{\partial e}{\partial c}(\omega, c) + \frac{\partial e}{\partial a}(\omega, a) = 0.$$

5. $$(e, i) = \frac{\partial e}{\partial c}(c, i) + \frac{\partial e}{\partial a}(a, i) = 0.$$

6. $$(i, \omega) = \frac{\partial i}{\partial c_3}(c_3, \omega) + \frac{\partial i}{\partial c}(c, \omega) = -\frac{\partial i}{\partial c_3} = \frac{1}{c \sin i} = \frac{1}{na^2\sqrt{1-e^2}\sin i}.$$

Further, from (5) we find:

(24) $$(\pi, a_i) = (\omega, a_i) + \frac{\partial \pi}{\partial i}(i, a_i) + \frac{\partial \pi}{\partial r}(r, a_i) + \frac{\partial \pi}{\partial z}(z, a_i) + \frac{\partial \pi}{\partial r'}(r', a_i).$$

In this formula, where

$(25)_1$ $$\frac{\partial \pi}{\partial i} = -\frac{cz\cos i}{r^2 z' \sin i},$$

$(25)_2$ $$\frac{\partial \pi}{\partial r} = -\frac{cz}{r^2 z'},$$

$(25)_3$ $$\frac{\partial \pi}{\partial z} = \frac{c}{z' r^2},$$

$(25)_4$ $$\frac{\partial \pi}{\partial r'} = -\frac{c}{\mu e},$$

we have only to substitute for a_i the letters a, e, ω, i. We then find:

7. $$(\pi, a) = \frac{\partial \pi}{\partial z}(z, a) + \frac{\partial \pi}{\partial r'}(r', a) = 0.$$

8. $$(\pi, \omega) = \frac{\partial \pi}{\partial i}(i, \omega) + \frac{\partial \pi}{\partial z}(z, \omega) = 0.$$

$$(\pi, e) = \frac{\partial \pi}{\partial r}(r, e) + \frac{\partial \pi}{\partial z}(z, e) + \frac{\partial \pi}{\partial r'}(r', e).$$

But, as is easily seen,

(26) $$(r', e) = \frac{\partial e}{\partial a}(r', a) + \frac{\partial e}{\partial c}(r', c) = \frac{\partial e}{\partial a}(r', a) = \frac{c^2}{\mu r^2},$$

because e being a homogeneous function of the same order of x, y, z and x', y', z', we must, as observed before, have $(r', c) = 0$; further,

(27) $$(r, e) = \frac{\partial e}{\partial a}(r, a) + \frac{\partial e}{\partial c}(r, c) = 0,$$

because $(r, c) = 0$, as can be easily verified; finally,

(28) $$(z, e) = \frac{\partial e}{\partial a}(z, a) + \frac{\partial e}{\partial c}(z, c) = \frac{2z'r}{\mu}.$$

Therefore,

9. $$(\pi, e) = \frac{\partial \pi}{\partial r'}\frac{c^2}{\mu r^2} + \frac{\partial \pi}{\partial z}\frac{2z'r}{\mu} = -\frac{c}{\mu a e} = -\frac{\sqrt{1-e^2}}{nea^2}$$

10. $$(\pi, i) = (\omega, i) + \frac{\partial \pi}{\partial z}(z, i) = -\frac{1}{c\sin i} + \frac{\cos i}{c \sin i} = -\frac{1-\cos i}{na^2\sqrt{1-e^2}\sin i}$$

Remains to find the expressions for the combinations of ϵ with a, e, ω, i, π.

It follows, from (6), that

(29) $$(\epsilon, a_i) = (\pi, a_i) + (-n\tau, a_i).$$

Now, formula (7) shows, that $(-n\tau, a_i) = -\frac{\partial n\tau}{\partial r'}(r', a_i)$ + a term having r' as a factor. As we have chosen $t = \tau$, i. e., $r' = 0$, we may write

(30) $$(-n\tau, a_i) = -\frac{\partial n\tau}{\partial r'}(r', a_i) = \frac{nr^2}{e\mu}(r', a_i).$$

Substituting in (30) the letters a, e, i, ω, π for a_i, we find:

$$(-n\tau, a) = 2\sqrt{\frac{a}{\mu}}$$

$$(-n\tau, e) = \frac{\partial e}{\partial a}(-n\tau, a) = \frac{1-e^2}{ena^2}$$

$$(-n\tau, \omega) = 0$$

$$(-n\tau, i) = 0$$

$$(-n\tau, \pi) = \frac{nr^2}{e\mu}(r', \pi) = 0.$$[1]

Hence

11. $$(\epsilon, a) = 2\sqrt{\frac{a}{\mu}}$$

12. $$(\epsilon, \omega) = 0$$

13. $$(\epsilon, \pi) = 0$$

14. $$(\epsilon, i) = -\frac{1-\cos i}{na^2\sqrt{1-e^2}\sin i}$$

15. $$(\epsilon, e) = -\frac{\sqrt{1-e^2}}{nea^2}(1-\sqrt{1-e^2}).$$

Demonstration of a Formula. By Frank H. Clutz.

Dr. Chessin, in his paper, "Note on Professor Newcomb's Development of the Perturbative Function," which appeared in the Astronomical Journal, No. 326, September 8, 1894, solves the following problem:

Given a set of functions,

$$\psi(0), \psi(1), \ldots, \psi(e), \ldots .$$

and the relation

$$(1) \quad \phi(i, p) = \psi(p) + f(p) \sum_{e=1}^{i} \phi(e, p-1)$$

connecting the functions $\phi(i, p)$ of i and p which take only positive integer values; to express the function $\phi(i, p)$ in terms of $\psi(0), \psi(1), \ldots$ Dr. Chessin gives as the solution the formula

$$\phi(i,p) = \psi(p) + \sum_{n=1}^{n=p} \frac{(i+n-1)!}{n!\,(i-1)!} f(p) f(p-1) \ldots f(p-n+1)\,\psi(p-n)$$

which differs from the one in the Astronomical Journal only in the notation. He gives it without demonstration—merely indicating the general method to be pursued. He further imposes the condition that $\phi(i, m) = 0$ for all negative values of m.

Following his indications, I offer the demonstration of the formula, omitting the last condition.

Relation (1) gives for $i = 1$:

$$\phi(1, p) = \psi(p) + f(p)\,\phi(1, p-1)$$
$$\phi(1, p-1) = \psi(p-1) + f(p-1)\,\phi(1, p-2)$$
$$\phi(1, p-2) = \psi(p-2) + f(p-2)\,\phi(1, p-3).$$
$$\ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots$$

---

[1] In (24) substitute r' for a_i. Then

$$(\pi, r') = \frac{\partial \pi}{\partial r}(r, r') + \frac{\partial \pi}{\partial z}(z, r').$$

But

$$(r, r') = 1$$

$$(z, r') = \frac{z}{r},$$

hence

$$(\pi, r') = \frac{\partial \pi}{\partial r} + \frac{z}{r}\frac{\partial \pi}{\partial z} = 0.$$

Making the proper substitutions and putting for brevity

$$\theta(n) \equiv f(p) f(p-1) \ . \ . \ . \ f(p-n+1) \psi(p-n),$$

we obtain the formula

$$\phi(1, p) = \psi(p) + \sum_{n=1}^{p+m} \theta(n) + \phi(1, -m-1) \prod_{n=0}^{p+m} f(p-n).$$

Proceeding in the same way we find for $\phi(2, p)$ and $\phi(3, p)$:

$$\phi(2, p) = \psi(p) + 2\,\theta(1) + 3\,\theta(2) + 4\,\theta(3) + \ . \ . \ . \ .$$
$$+ (p+m+1)\phi(2, -m-1) \prod_{n=0}^{p+m} f(p-n)$$

$$\phi(3, p) = \psi(p) + 3\,\theta(1) + 6\,\theta(2) + 10\,\theta(4) + \ . \ . \ . \ .$$

This at once suggests the formula:

$$\phi(i, p) = \psi(p) + \sum_{n=1}^{p+m} \frac{(i+n-1)!}{n!\,(i-1)!}\,\theta(n)$$
$$+ \frac{(i+p+m-1)!}{(p+m)!\,(i-1)!}\,\phi(i, -m-1) \prod_{n=0}^{p+m} f(p-n),$$

or using the notation of Permutations and Combinations,

$$_nC_r = \frac{n!}{r!\,(n-r)!} \text{ and putting } i+n = s.$$

$$(2) \quad \phi(i, p) = \psi(p) + \sum_{n=1}^{p+m} {}_{s-1}C_{i-1}\,\theta(n)$$
$$+ \frac{(i+p+m-1)!}{(p+m)!\,(i-1)!}\,\phi(i, -m-1) \prod_{n=0}^{p+m} f(p-n).$$

As formula (2) holds for $i=1$ and $i=2$, it remains only to prove that supposing it true for i, it is true for $i+1$. From relation (1) we find

$$\phi(i+1, p) = \phi(i, p) + f(p)\,\phi(i+1, p-1).$$
$$(3) \quad \phi(i+1, p-1) = \phi(i, p-1) + f(p-1)\,\phi(i+1, p-2).$$

Making the proper substitutions

$$\phi(i+1, p) = \psi(p) + \sum_{n=1}^{p+m} {}_{s-1}C_{i-1}\,\theta(n)$$
$$+ \frac{(i+p+m-1)!}{(p+m)!\,(i-1)!}\,\phi(i+1, -m-1) \prod_{n=0}^{p+m} f(p-n)$$
$$+ \sum_{n=1}^{p+m} {}_{s-2}C_{i-1}\,\theta(n)$$
$$+ \frac{(i+p+m-2)!}{(p+m-1)!\,(i-1)!}\,\phi(i+1, -m-1) \prod_{n=0}^{p+m} f(p-n)$$
$$+ \ . \ . \ . \ . \ . \ . \ .$$

The coefficient of $\theta(n)$ is

$${}_{s-1}C_{i-1} + {}_{s-2}C_{i-1} + \ . \ . \ . \ + {}_{i-1}C_{i-1} = {}_sC_i,$$

(vid. Chrystal's Algebra, Part II. p. 8).

Therefore if

$$\phi(i, p) = \psi(p) + \sum_{n=1}^{p+m} {}_{s-1}C_{i-1}\,\theta(n)$$
$$+ \frac{(i+p+m-1)!}{(p+m)!\,(i-1)!}\,\phi(i, -m-1) \prod_{n=0}^{p+m} f(p-n)$$

then

$$\phi(i+1, p) = \psi(p) + \sum_{n=1}^{p+m} {}_sC_i\,\theta(n)$$
$$+ \frac{(i+p+m)!}{(p+m)!\,i!}\,\phi(i+1, -m-1) \prod_{n=0}^{p+m} f(p-n).$$

This proves formula (2) for all positive integer values of i and p.

Relation (3) may also be put in the form

$$\phi(i-1, p) = \phi(i, p) - f(p)\,\phi(i, p-1).$$

By use of (2),

$$\phi(i-1, p) = \psi(p) + \sum_{n=1}^{p+m} {}_{s-1}C_{i-1}\,\theta(n)$$
$$+ \frac{(i+p+m-1)!}{(p+m)!\,(i-1)!}\,\phi(i, -m-1) \prod_{n=0}^{p+m} f(p-n)$$
$$- \sum_{n=1}^{p+m} {}_{s-2}C_{i-1}\,\theta(n)$$
$$- \frac{(i+p+m-2)!}{(p+m-1)!\,(i-1)!}\,\phi(i, -m-1) \prod_{n=0}^{p+m} f(p-n).$$

Here the coefficient of $\theta(n)$ is

$${}_{s-1}C_{i-1} - {}_{s-2}C_{i-1} = {}_{s-2}C_{i-2}$$

$$\therefore \phi(i-1, p) = \psi(p) + \sum_{n=1}^{p+m} {}_{s-2}C_{i-2}\,\theta(n)$$
$$+ \frac{(i+p+m-2)!}{(p+m)!\,(i-2)!}\,\phi(i, -m-1) \prod_{n=0}^{p+m} f(p-n).$$

Hence formula (2) is true for all integer values of i whether positive or negative.

If we suppose $\phi(i, m) = 0$ for all negative values of m, we obtain the formula given by Dr. Chessin:

$$\phi(i, p) = \psi(p) + \sum_{n=1}^{p} \frac{(i+n-1)!}{n!\,(i-1)!}\,\theta(n).$$

Note on the Mass of the Asteroids. By B. M. ROSZEL.

In the *Circular* for May, 1894, I published a preliminary note on the probable mass of the Asteroids. I add here four values of the combined mass of three hundred and eleven of these bodies, whose orbits are given in the *Berliner Astronomisches Jahrbuch* for 1894.

Estimates of the diameters of individual members of the Asteroid group have been made by Barnard (Monthly Notices R. A. S., Vol. LIV, No. 9), Pickering (H. C. O. Annals, Vol. XI), Müller (*Publicationen des Astro-phys. Obs. zu Potsdam*), Tacchini and Millosevich (*Astr. Nachr.* No. 2363), Argelander and Stone.

I have not used the earlier determinations of Argelander and Stone, as they differ very materially from those made with more accurate instruments. Tacchini and Millosevich give a diameter for Vesta which agrees closely with that given by Müller on the hypothesis that the albedo of Vesta is equal to the albedo of Mercury. I have not thought it desirable to derive the mass from this value, as my object is to find the probable limits of the mass rather than an accurate determination of the mass itself.

In what follows, the values of the mass are based upon the photometric determinations of the diameter of Vesta, by Pickering and Müller, and the direct measures of the diameters of Ceres, Pallas, and Vesta by Barnard.

I have reduced the volumns of all the Asteroids to the volumn of Vesta, except when Barnard's measures are the basis, in which case I computed the volumns of Ceres and Pallas separately, and added them to the combined volumn of the remaining three hundred and nine.

Assuming the albedo constant and a constant density equal to the density of Mars, I have obtained the following numbers:

Combined Volumn of 311 Asteroids, - - - 5.185 Volumns of Vesta.
" " omitting Ceres and Pallas, - 2.684 " " "

Volumn of Vesta, in terms of Volumn of Mars.

(1) from Pickering's estimate of the diameter of Vesta, assuming the albedo = albedo of Mars, - - - - = 0.00022
(2) from Müller's (1) estimate of the diameter of Vesta, assuming the albedo = albedo of Mars, - - - = 0.00065
(3) from Müller's (2) estimate of the diameter of Vesta, assuming the albedo = albedo of Mercury, - - - = 0.00129
(4) from Barnard's estimate of the diameter of Vesta, - - = 0.00018

Combined mass of 311 Asteroids, in terms of mass of Mars, from Pickering's, estimate, as above, - - - - - = 0.00112

from Müller's, estimate, as above, (1) - - - - = 0.00336
" " " " " (2) - - - - = 0.00666
" Barnard's, measures, - - - - - - - = 0.00273

Wherever it was necessary, I reduced all determinations of the diameter of Vesta to the values corresponding to the magnitude of Vesta, as given in the *Jahrbuch*, and I have taken 4230 miles for the mean diameter of Mars.

From the above it appears that the mass is about .026 of the mass of the moon.

Observations of the Transit of Mercury, 1894, November 10. By Charles Lane Poor.

The observations were made with the Equatorial and with the 3-inch finder of the same. The equatorial has a clear aperture of 10 inches and a focal length of 142 inches. A negative eyepiece, giving a magnifying power of 95, was used. On account of the bad condition of the atmosphere this was the highest power that could be used. The times of observation were recorded on the new Hoffman chronograph, which was run in connection with the sidereal clock. The clock corrections were determined by transit observations made on several nights between November 2nd and 15th, some of these being made during the early evening of the 10th, or within a few hours of egress. As finally adopted the clock corrections were:

$$\text{At time of II contact} - 44.48^{a.}$$
$$\text{" " " III " } - 44.68$$

The following is a transcript from the original chronograph readings and notes; the Eastern Standard times of contact, however, have been deduced from the observed sidereal times and inserted.

Contact.	Observer.	Instrument.	Chronograph Readings.	Eastern Standard Times.	Notes.
I	Poor	E			lost
	Jewell	F			"
			h. m. s.	h. m. s.	
II	Jewell	F	14 12 4.1	10 58 35.1	
	Poor	E	12 6.1	58 37.1	a
III	Poor	E	19 25 12.1	4 10 51.6	b
	Clutz	F	25 13.0	10 52.5	
	Poor	E	25 17.2	10 56.7	c
IV	Poor	E	19 27 10.8	4 12 50.0	d
	Clutz	F	27 12.0	12 51.2	

Notes.

E = equatorial, F = finder.

a. Observation good; heavy jars, caused by passing cars, just previous to contact.

b. Contact observed through rift in the clouds; definition very poor; much "boiling" at edge of disc. *b*, last glimpse of sunlight between the discs of Mercury and Sun: *c*, the two seem in perfect contact.

d. Much boiling, observation difficult.

Measurements of Double-stars, 1893-1894. Arranged by F. H. Clutz.

The following measures of Double-stars were made by students of the University during the years 1893-94. The results are given in the following table, and an inspection shows that they are in close accord with similar measures made elsewhere.

The measures were made with the 10 inch equatorial, using a magnifying power of 300. From four to eight direct measures, both of position angle and distance, were made on each star, each evening, and the means taken. When the same star was observed on more than one night by the same student, the mean result is given, and the number of nights on which observations were made is indicated.

Object.	R. A.	Dec.	Angle.	Distance.	Observer.	Nights.	Date, 1890 +
38 Geminorum, Σ 982.	h. m. 6 47.3	13° 20′	158°.40	6″.71	Clutz.	2	4.20
δ Geminorum, Σ 1066.	h. m. 7 13.0	22° 12′	206.36	——	Lewis.	2	4.12
			205.60	7.15	Clutz.	2	4.13
			207.20	7.29	Stoner.	1	4.16
Castor, Σ 1110.	h. m. 7 27.0	32° 1′	230.96	5.85	Clutz.	1	3.18
ζ Cancri, Σ 1196.	h. m. 8 5.3	18° 1′			Clutz.	2	4.23
A B			23.90	1.16			
A C			114.11	5.20			
B C			129.35	5.35			
ε Hydrae, Σ 1273.	h. m. 8 40.4	6° 52′	226.07	3.72	Stoner.	1	4.16
γ Leonis, Σ 1424.	h. m. 10 13.4	20° 27′	116.16	4.06	Ebaugh.	2	3.24
				3.85	Harrison.	1	4.18
			114.83	3.88	Clutz.	1	4.19
ι Leonis, Σ 1536.	h. m. 11 17.6	11° 12′	57.55	3.06	Harrison.	1	4.21
			59.52	3.11	Stoner.	1	4.22
γ Virginis, Σ 1670.	h. m. 12 35.6	-0° 47′	152.30	5.78	Clutz.	2	3.33
			153.21	6.14	"	1	4.19
			153.71	6.17	Harrison.	1	4.19
Mizar, Σ 1744.	h. m. 13 19.1	55° 33′	149.20	14.31	Ebaugh.	1	3.32
			149.54	14.10	Watts.	2	4.18
ϵ^1 Lyrae, Σ 2382.	h m. 18 40.4	39° 33′	12.4	3.33	Stoner.	1	4.35
ϵ^2 Lyrae, Σ 2383.	h. m. 18 40.4	39° 29′	129.5	3.11	Stoner.	1	4.35

BOTANY.

The Crystallization of Cellulose. By D. S. Johnson.

In "La Cellule" for 1892, Eugene Gilson of the University of Ghent published some work on cellulose, in which he obtained the latter in the form of so-called crystals. He states he has obtained these from the tissues of a considerable number of flowering plants, Cryptogams, Gymnosperms, many of the Algae, and from the tests of one or two Ascidians, but has not been able to obtain them in the case of any of the Fungi.

During the past year I repeated Gilson's work in the Biological Laboratory of Johns Hopkins University, on many of the plants used by him, and have also worked on some others, among them several Fungi, together with many animal tissues. In the case of all the chlorophyll-bearing plants of which I had good material, I obtained results entirely confirming the work of Gilson, as to the derivation of the crystal-like bodies.

The method for obtaining the crystals is as follows: Sections of the tissue, as beet-root for example, were first soaked in a 2 per cent. solution of KOH, for half an hour, to dissolve the protoplasm in the cells. These were then washed thoroughly in H_2O, and then allowed to stand for 2 or 3 hours in Schweitzer's reagent, from which it was transferred to strong NH_4OH for a short time. They are then either cleared with dilute HCl and stained with chlorozinc iodide, or before clearing are stained with Congo red.

The so-called crystalline bodies are then seen within the cell cavities, and have a somewhat radial structure. Few or none of these are seen outside the cell cavity, thus tending to prove that the solution of cellulose in Schweitzer's reagent is not readily diffusible through the cell membrane, a conclusion which is strengthened by the fact that after protracted stay in Schweitzer's reagent, the amount of cellulose within the cell cavity is not diminished. These bodies, when examined under the polariscope, do not, in spite of their crystal-like appearance, have any effect on polarized light.

My work on Fungi gave results similar to those of Gilson. Although the Fungi gave a good cellulose reaction with chlorozinc iodide before treatment with Schweitzer's, the blue staining substance would not dissolve from the cell walls, even after long treatment with the latter reagent, the color given by chlorozinc iodide being as strong and evenly distributed in the tissues after a week in Schweitzer's reagent, as at first.

Among the animal tissues, of which I tried many not mentioned by Gilson, were several Ascidians and many of the Arthropod and Molluscan tissues mentioned by Ambronn as giving a characteristic cellulose reaction with the iodine reagents.

With these again, as with Fungi, I was unable to dissolve out the blue staining substance with Schweitzer's reagent.

My work on animal tissues thus giving results contradictory to those obtained in the one case mentioned by Gilson, of crystals in the test of Phallusia mammillata, I cannot with certainty offer an explanation of the difference of our results. I can only say, that at first I thought I had obtained the crystal-like bodies in the test of Salpa. Although appearing at first like the cellulose bodies, and seemingly colored blue, careful examination showed that the color came from that of the deeply stained surrounding tissues, from which the blue staining substance had not been removed to any preceptible degree by treatment with Schweitzer's reagent. Moreover these bodies, by examination with the polariscope, showed themselves to be true crystals, thus differing from the cellulose bodies.

Our conclusion then must be, that if the blue staining substance present in the Fungi and certain animal tissues is cellulose, it must be combined in some different way than in the tissues of green plants.

That true cellulose is present in tunicates seems to admit of little doubt, after the work of Winterstein in deriving dextrose from these tissues, while nothing additional to Ambronn's work proves its presence among the Arthropods.

A fuller account of my own work, and also a more detailed abstract of Gilson's paper, is now in press and will appear in The Botanical Gazette for January, 1895.

Some Rare Ferns found near Baltimore. By C. E. WATERS.

[Selections from the Proceedings of the Baltimore Field Club, No. I.]

The Baltimore region is an especially favorable one in which to find ferns, 41 species having been catalogued by Mr. Sollers in 1888. The following are some of our rarer species:

Cheilanthes vestita, Swartz. On rocks at Loch Raven, and near Hollofield on the Patapsco. Very scarce and local.

Pellaea atropurpurea, Link. On limestone rocks north of Towson, and above Meredith's Bridge at the Gunpowder. On a boulder at Asbestos Ridge (Mr. G. H. Gray). Found also by Mr. Sollers near Relay.

Woodwardia Virginica, Smith. Was found at southern limits of our map by Mr. Sollers, who has also found,

Asplenium angustifolium, Michx.

Asplenium Bradleyi, D. C. Eaton. Was found by Mr. J. H. Brummell at the Patapsco on rocks. This exceedingly rare fern has never been found here before.

Camptosorus rhizophyllus, Link. Grows in a number of localities.

Phegopteris Dryopteris, Fée. Was found for the first time in this locality on May 19, 1894, near Towson.

Aspidium cristatum, Swartz. Grows in several places.

Aspidium spinulosum, Swartz.

Aspidium spinulosum var. intermedium, D. C. Eaton.

Aspidium spinulosum var. dilatatum, Horneman.

These have all been found rather sparingly by me at Towson, Pikesville, and Glenburnie, respectively.

Lygodium palmatum, Swartz. Mr. Brummell has found this in a swamp on the Washington turnpike. It has been found in one or two other localities.

Cystopteris fragilis, Bernh. Has been seen at Loch Raven.

Ophioglossum vulgatum, Link. Found by Dr. Barton near Pikesville.

Selaginella rupestris, Spring. Grows at Loch Raven.

Phegopteris polypodioides, Fée. At Loch Raven, June 23, 1894.

Phegopteris Dryopteris, Fée. Found in a railroad cut south of Towson on May 19, 1894.

Onoclea sensibilis L. var. obtusilobata, Torrey. At Aigburth Park, near Towson, August 23, 1894.

Onoclea Struthiopteris, Hoffm. On the east bank of the Gunpowder river, a couple of miles north of Meredith's Bridge, June 18, 1894.

Lycopodium annotinum, Link. On the south side of Loch Raven, about a mile below Meredith's Bridge, on August 31, 1894.

These last five species are new for our locality.

Aspidium Goldieanum, Hooker. Found on the Franklin road by Mr. J. H. Brummell, October 30, 1894. He has also known a locality near Towson for a number of years.

EQUISETACEAE.

Equisetum arvense L. var. triangulare nov. var. Character of the type except that the branches are *three*-sided; their teeth three at each joint. Similar in size and general aspect to the type. Found everywhere around Baltimore, outnumbering the typical form by at least ten to one.

UNIVERSITY SCHOLARSHIPS, 1894-95.

The Board of University Studies, at a meeting held January 9, awarded University Scholarships to the gentlemen named below:

W. D. BALL (S. B., University of Michigan). *Electricity.*
H. L. CLARK (A. B., Amherst College). *Biology.*
H. E. EBELING (Gettysburg Theological Seminary). *German.*
CHARLES HOEING (A. B., Kentucky State College). *Latin.*
W. E. HENDERSON (A. B., University of Wooster). *Chemistry.*
O M. JOHNSTON (A. B., Mississippi College). *Romance Languages.*
J. H. LATANE (A. B., Johns Hopkins University). *History.*
G. J. LAING (A. B., University of Toronto). *Latin.*
EBENEZER MACKAY (A. B., Dalhousie University). *Chemistry.*
J. S. MORRIS (S. B., Haverford College). *Mathematics.*
C. C. SCHENCK (A. B., Johns Hopkins University). *Physics.*
J. A. SCOTT (A. B., Northwestern University). *Greek.*
G. O. SMITH (A. B., Colby University). *Geology.*
J. W. TUPPER (A. B., Dalhousie University). *English.*
W. A. WETZEL (A. B., Lafayette College). *Economics.*

University Scholarships were awarded in June last, to the gentlemen named below:

E. J. BECKER (A. B., Johns Hopkins University). *English.*
G. S. MAYNARD (A. B., Johns Hopkins University). *Electricity.*
W. A. NITZE (A. B., Johns Hopkins University). *Romance Languages.*
MILTON REIZENSTEIN (A. B., Johns Hopkins University). *Economics.*
F. R. RUTTER (A. B., Johns Hopkins University). *Economics.*

The two prizes of $30. and $20. respectively, offered to members of the undergraduate class that entered in October, 1893, were awarded in November, 1894, to CHARLES BURNET TORSCH (the first prize) and ARTHUR WEBSTER MACHEN, JR., (the second prize). Their subjects were respectively,—"A Review of Lodge's Life of Washington" and "Why Americans should study Greek." The Committee of Award consisted of Professors Adams, Browne, and Smith.

At the recent commencement of the University of Pennsylvania, the degree of Doctor of Medicine, Honoris Causâ, was conferred upon Professor W. H. WELCH, M. D., LL. D., of the Johns Hopkins University.

Professor HENRY A. ROWLAND has recently been elected a foreign member of the Reale Accademia dei Lincei of Rome, in the section of physics.

A DEBATING SOCIETY has recently been organized by the students, and now holds its meetings in Levering Hall, on Monday evenings.

The NINETEENTH ANNUAL REPORT of the President of the University was issued in December and copies may be had on application.

NOTES ON RECENT PUBLICATIONS.

The Genus Salpa. A Monograph, with 57 plates. By W. K. Brooks, Ph. D., LL. D., Professor in the Johns Hopkins University. Memoirs of the Biological Laboratory of the Johns Hopkins University, II. Baltimore: The Johns Hopkins Press, 1893.

(A review reprinted from *Natural Science*, London, for June, 1894.)

Salpa is itself so interesting an animal and belongs to so interesting a group that the results of Professor Brooks's researches deserve at once a fuller and a less technical account than is given usually in a review. The account need not be technical, for all morphologists who take a special interest in the Tunicates will have to pore over this magnificent memoir. Even to those who pay no special attention to them, the Tunicates are interesting because they seem to possess, more certainly than any other group, indications that they represent the stock from which the vertebrate animals were derived. But in addition to this general interest, Dr. Brooks has brought before us matter so surprising that it may well attract the notice of all who care for the problems of nature.

Salpa is a transparent swimming Tunicate, which may be compared to a barrel, open at both ends. It is, in fact, an enormous Pharynx which swims through the water, gulping great mouthfuls at every contraction of its muscles. A rod-like gill stretches from above the wide open mouth in

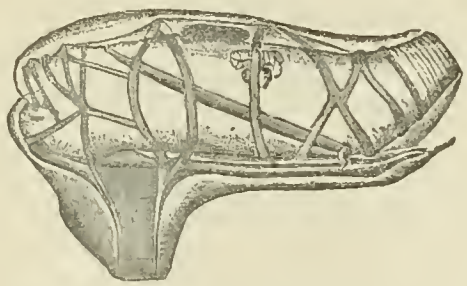

Fig. 1.—*Salpa pinnata:* a specimen of the aggregated form seen from the left side.

front, through the hollow of the barrel, to below the posterior aperture behind; but this is so narrow that it offers no obstruction to the flow of water through the animal. Along the ventral line of the inside of the barrel runs a ciliated, mucus-secreting band, which is the homologue of the endostyle in ascidians and *Amphioxus*. At the posterior end of the barrel, in a thick mass, are contained the viscera, and this mass is the only part of the animal which is not transparent. Representing the hoops of the barrel are a number of muscular bands by the contraction of which the water is driven through the body. The whole animal is surrounded by a thick, tough, transparent "mantle."

The food of *Salpa* consists of minute organisms like diatoms, radiolarians, and so forth, and as these are practically unlimited in quantity on the ocean surface where *Salpa* lives, *Salpæ* are often found swarming in numbers beyond description. They vary in size from a quarter of an inch to eight inches. Though most abundant in the tropics, they are found from further north than Scotland and Norway to beyond Cape Horn and the most southerly parts of Australia. "They are abundant," says Dr. Brooks, "only after the water has been for some time undisturbed by winds: and as prolonged calms are most frequent in warm seas, these waters are most favorable for the development of these animals, which multiply with most astonishing rapidity. The smaller species are often so abundant that for hundreds of miles any bucketful of water dipped up at random, will be found to contain hundreds of them. In such places collecting with the surface net becomes impracticable, for almost as soon as the net is dropped into the water, it becomes choked with a mass so that nothing can enter it."

Since the time of the poet and naturalist Chamisso, it has been known that there are two generations in the life cycle of *Salpa*. These are a generation of solitary individuals, and a generation of individuals aggregated into chains or clusters. The specific characters of the two generations differ from each other so widely, that without rearing them there is no possibility of determining which simple and solitary forms belong to each other. The solitary *Salpa* is born from an egg which is carried within the body of the aggregated *Salpa*, and the embryo, by means of a nutritive placenta, is nourished during its development from the blood of the aggregated form. The aggregated *Salpæ* are produced asexually by budding from a stolon within the body of the solitary form. The eggs arise at an exceedingly early stage in the development of the animal. Thus the curious result happens that three generations are simultaneously present in the same animal. A solitary *Salpa* contains a developing chain of the individuals of the aggregated form, and within these are already present the eggs which are to give rise to the next generation of solitary forms. Actually, the germ-cells can be seen in a solitary form before the stolon is visible which is to give rise to the generation of individuals in which the germ-cell will develop. As the stolon forms, it includes within it the mass of germinal cells; and as the stolon elongates to form the chain of individuals, the mass of germ-cells also elongates and becomes pulled out, so that a single egg-cell is shut off in each individual of the aggregated series. This chain of eggs is enclosed in a chain of follicle-cells, as in Fig. 2, which, however, does not show the ventral band of thick epithelium which ultimately gives rise to the testes. From these follicle-cells short fertilising ducts grow out to the wall of the cloaca of each individual of the chain. Through these ducts fertilisation takes place, and each salp of the chain thus comes to contain a fertilised egg, which is to give rise to a solitary individual. In Fig. 1 is

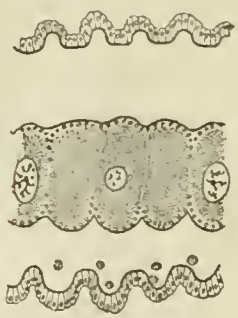

Fig. 2.

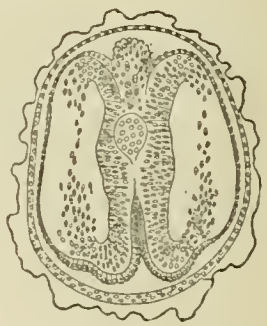

Fig. 3.

Fig. 2.—Chain of germ-cells surrounded by follicle-cells, lying in a blood canal.
Fig. 3.—Section through a young embryo.

shown an individual of the chain-salp of *Salpa pinnata*, with the developing embryo attached to the wall of the cloaca. The egg and the embryo in its youngest stages are really outside the wall of the cloaca, in one of the blood sinuses of the chain-salp, but attached to the cloaca by the fertilising duct which opens into the cloaca. As the embryo grows it pushes into the wall of the cloaca, without, however, breaking through, and so becomes suspended in a sac, which is really the in-pushed wall of the cloaca, and which opens into the blood sinus. This sac remaining open to the blood sinus of the chain-salp, expands considerably, and becomes the placenta, by which the embryo continues to get its nourishment from the blood of the chain. The edge of the cloaca, round the place where the embryo is pushing in, grows in as a double fold, the hollow between the layers of which is, of course, in continuity with the blood space in which the embryo was formed. This double fold comes to form a special sac, the amnion or embryo-sac, which opens into the cloaca by a small pore, the space left by the edges of the fold not completely meeting each other. Thus a horizontal section cut through, such an embryo as hangs into the cloaca in Fig. 1, would pass first through the outer wall of the amnion, next through the blood space, thirdly through the inner wall of the amnion, fourthly through the brood-pouch, which is part of the cloaca of the chain-salpa, next through the epithelial capsule, then through the embryo (*see* Fig. 3). The embryo-sac, however, does not increase in size, and the growing embryo rapidly pushes itself through the small pore, and comes to hang directly into the cloaca.

Within these complicated membranes a process of the most astonishing nature has been going on. The fertilised egg-cell was at first surrounded by

a layer of follicle-cells, which, themselves being derived from the germinal cells, differ from the egg only in not being actually developed into mature eggs and becoming fertilised (Fig. 4). The egg-cell divides slowly, the follicle cells divide rapidly, and many of them push their way in towards the centre of the mass, and actually push apart those cells which result from the division of the egg-cell. During this time constant migration of nuclei takes place from the ingrowing follicle-cells to the cells which have come from the egg-cell. No doubt this is a process of nutrition, not very different in kind from some known methods, although it is at least curious to find nuclear matter being added from an extrinsic source to the developing embryo. If it be remembered that most now believe that the nucleus of a fertilised embryo is derived equally from the nuclei of the male and female generative cells, that this nuclear matter is the bearer of the inherited qualities of the embryo, and that by subsequent assimilation and growth it gives rise to the entire nuclear matter of the new organism, then it will be sufficiently astonishing to find the nuclear matter of any cells serving simply as nutritive material. But, if this is difficult to understand, what is to be said of the other process, by which the embryo is, so to say, broken in pieces during its development? For what else is the separation of the segmentation spheres by the intruding follicle-cells? Driesch and Wilson have shown cases where the separation of the first two spheres by artificial means resulted in the formation of twin embryos. Here is a natural parallel, with the remarkable difference that not many embryos, but only a single embryo comes from the separate pieces, which, after pursuing for a time a separate course, re-unite. But more astonishing matter remains. The actual embryo is first blocked out in follicle-cells.

FIG. 4.—Fertilised egg-cell surrounded by follicle-cells.

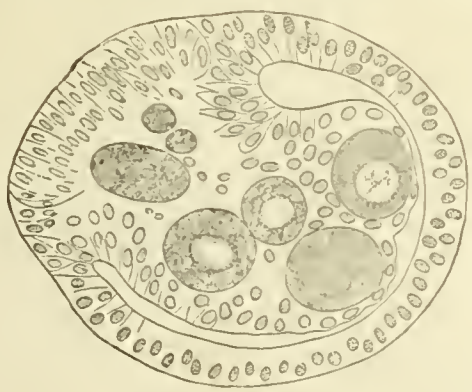

FIG. 5.—The segmentation spheres lying in a mass of follicle-cells that have grown in between them.

"These form layers and undergo foldings and other changes which result in an outline or model of all the general features in the organisation of the embryo. While this is going on, the development of the blastomeres is retarded, so that they are carried into their final positions in the embryo while in a very rudimentary condition. Finally, when they have reached the places which they are to occupy, they undergo rapid multiplication and growth, and build up the tissues of the body directly, while the scaffolding of follicle-cells is torn down and used up as food for the true embryonic cells."

"An imaginary illustration may help to make the subject clear. Suppose that while carpenters are building a house out of wood brickmakers pile clay on the boards while they are carried past, and shape the lumps of clay into bricks as they find them scattered through the building where they have been carried with the boards. Now, as the house of wood approaches completion, imagine that brickmakers build a brick house over the wooden framework, not from the bottom upwards, but here and there wherever the bricks are to be found, and that as fast as parts of the brick house are finished the wooden one is torn down. To make the analogy complete, however, we must imagine that all the structure which is removed is assimilated by the bricks, and is thus turned into the substance of new bricks to carry on the construction."

Fig. 5 shows a stage where the cells resulting from the early divisions of the egg-cell have been separated by the intruding follicle-cells. Figures showing the outlining of the embryo by the follicle-cells would be too complicated to reproduce without elaborate explanation and coloring, as in the beautiful illustrations of Dr. Brooks's monograph. But it must be repeated that, down to details like the structure of the nervous system, this system of preformation in follicle-cells occurs. The fate of all the structures formed of follicle-cells is the same. They degenerate, forming food for the true embryonic cells. Former observers had described something like this. Salensky, for instance, stated that the embryo of *Salpa* began as a true embryo, but afterwards the accessions from the follicle wall turned the embryo into a bud. He believed, therefore, that its development was to be compared in no way with ordinary embryological processes. Dr. Brooks considers that, however abnormal, it is a true embryo, and the appearance of budding is illusory. Certainly his figures bear out this view completely.

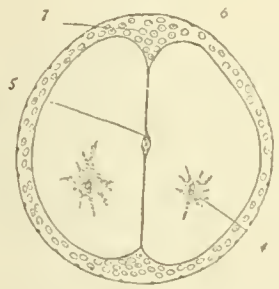

FIG. 6.—Egg of *Distaplia*: the first division has occurred, and follicle-cells are growing in between the segmentation spheres.

Dr. Brooks believes that comparative embryology has established that the ancestors of all the Tunicates once possessed small eggs with little or no food-yolk, and that these small eggs divided completely, giving rise first to a mulberry-shaped mass and then to a hollow sphere of cells. By the inpushing of the cells at one point they gave rise to a little two-walled sac or gastrula. In many groups of vertebrates this simple form of development becomes impossible; for the egg-cell becomes so loaded with inert food-yolk that it does not divide completely, but the shape of the embryo is modified precisely in proportion to the amount of food-yolk present. The yolk is not distributed in the same way in all the animals possessing it. In some cases it is restricted chiefly to the cells which are to form the alimentary canal. In others, as anyone who has examined a young tadpole must know, all the cells are packed with yolk-spheres. In *Pyrosoma*, a near ally of *Salpa*, there is a large amount of food-yolk, and that is massed not in the future digestive-cavity but in the body-cavity. But the food-yolk is aided by follicle-cells, which push their way into the developing cells and are absorbed by

FIG. 7.—Diagram of a blastosphere where follicle-cells are passing into the segmentation cavity.

them. Dr. Brooks suggests a method by which the peculiar arrangement in *Salpa* might have come about. Fig. 6 represents an actual stage in the development of *Distaplia*, which has cells bloated with food-yolk, but still able to divide completely. Two segmentation spheres are represented, surrounded by a number of follicle-cells, some of which are pushing their way in between the segmentation spheres, and which are absorbed as food. Fig. 7 represents an imaginary stage in the development of a form which has lost food-yolk, and which, in consequence, has a large hollow segmentation cavity into which follicle-cells are migrat-

ing from the layer of follicle-cells surrounding the embryo. In Fig. 8 is represented the invaginating stage of such an embryo. The follicle-cells are, of course, inside the segmentation cavity, but they also follow the invagination, and fill the hollow that usually forms the digestive tract. Now in Fig. 9 is represented a similar stage, but in a case where the follicle-cells, instead of migrating irregularly, arrange themselves as a regular epithelium.

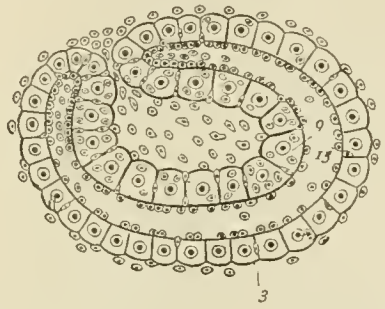

FIG. 8.—Diagram of invagination in embryo such as that of Fig. 7.

In it is to be seen the ordinary invaginate gastrula, but the cells derived from the follicle arrange themselves as a regular cast of this. In subsequent development it is easy to see that the follicular epithelium might follow all the developments and changes of the real embryonic cells, so that each fold of tissue would be formed not only of embryonic cells, but of follicle-cells closely adherent. Dr. Brooks supposes that *Salpa* had such a history, and

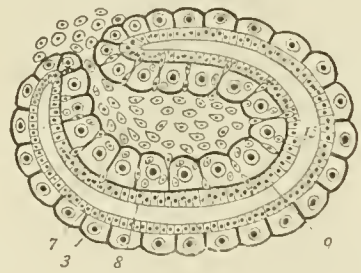

FIG. 9.—Diagram of the gastrula of an embryo in which the follicle-cells form an epithelium.

that, when this condition of things was reached, the development of the embryonic cells began to lag behind the development of the follicle-cells, which originally merely followed the course of the cells they came to anticipate. In Fig 10 is shown the case of an embryo in which the invagination has taken place in follicle-cells, but where the real embryonic cells are so delayed that they appear merely as scattered segmentation spheres, and

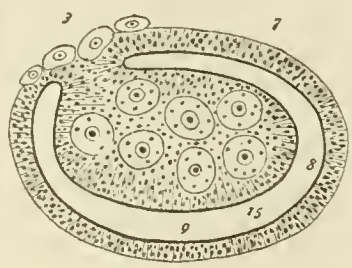

FIG. 10.—Diagram of an embryo in which the segmentation spheres delay development.

this last figure is merely a diagrammatic representation of what actually occurs in *Salpa*, as may be seen by comparison with Fig. 5.

There has already appeared in *Natural Science*, vol. iii., p. 223, a brief account of the interesting views to which the development of *Salpa* has led Dr. Brooks. As that account was based on three chapters of this monograph which appeared separately, it is necessary now only to remind readers that Dr. Brooks has come to the interesting conclusion that a simple pelagic form, of which *Appendicularia* is the nearest living representative, is the common ancestor of the Ascidians and the Chordates; and that consequently there can be only among such organs as are found in simple transparent, surface-living creatures any homologies between vertebrates and invertebrates; arguments linking annelids, crustacea, and so forth with vertebrates, because of similarities in segmentation, body-cavity, etc., are dismissed as empty shadows of morphological dreams.

In this short attempt to bring to the notice of the general scientific public some of the more interesting results of Dr. Brooks's work, it has been impossible to touch upon many of the more complicated and technical matters which all specialists will have to study with attention in this great contribution to scientific literature.

Lehrbuch der Botanik für Hochschulen, von Dr. Eduard Strasburger, Dr. Fritz Noll, Dr. Heinrich Schenck, Dr. A. F. W. Schimper. Mitt 577 Abbildungen. pp. 558. 8o. Jena, G. Fischer, 1894.

In this volume the four Bonn botanists have coöperated to produce a text-book of Botany for students who desire to obtain a general view of the status of the science and to master its essential principles, without intending to become botanists. It is what its title implies, a *text-book* for general students rather than a hand-book for special students and investigators. Its object and the limited size which this necessitates have made it impossible to allude, except in the briefest way, to many most interesting and important lines of botanical research. The same reasons have, presumably, determined the absence of reference even to the classics of botanical literature, an omission which many users of the book will, with good reason regret.

The scientific reputation of the authors should be a guarantee of accuracy in detail, and the collaboration of several writers would lead one to expect a more even treatment of the different branches of the subject than is found in many text-books by single authors. And in neither of these respects is one disappointed; while frequent cross-references show that the collaboration of the authors has been real.

The brief, but pithy, Introduction and the first half of the "General Botany," that on Morphology, are by Strasburger. The chapter on "External Morphology" contains the essentials of the matter in very concise form. That on "Internal Morphology," or Histology, is admirably written and presents that usually dull subject interestingly, clearly, and consistently.

The second half of the general part is by Noll; and though one often wishes for more detailed discussions of many interesting or disputed points than the limitations of space permit, the presentation of fundamental physiological facts and principles is forceful and sometimes almost epigrammatic.

The second part of the volume, "Special Botany," contains accounts of the various Cryptogamic groups by Schenck, and of the Phanerogams by Schimper. The first of these is the less satisfactory, being distinctly too brief, especially as regards the Thallophytes, though accurate for the most part. The systematic discussion of the Phanerogams is unusually full for a general text-book, and may be especially commended to American students as a detailed exposition of the classification of Braun and Eichler, an arrangement of the families of flowering plants far more natural and rational than the Candollean system, which holds its place with such extraordinary tenacity among English-speaking botanists. In the discussion of all the groups attention is constantly given to officinal and poisonous plants, in deference to the needs of students of medicine and pharmacy, who form an overwhelming majority of those who follow the botanical courses in German universities.

The illustrations throughout the book are abundant and excellent; and the several colored ones of poisonous plants, which have been, by a new process, inserted like wood-cuts, in the text, are decidedly successful.

The volume can, then, be heartily recommended to those for whom it is written; while its extraordinarily low price ($2.00, in cloth) will give it a decided advantage and a wide influence.

J. E. HUMPHREY.

PROCEEDINGS OF SOCIETIES.

Scientific Association.

Officers for 1894–95:
Professor IRA REMSEN, *President;* Professor W. H. HOWELL, *Vice-President;* Dr. C. L. POOR, *Secretary.*

November 15, 1894.—One hundred and sixteenth regular meeting. Professor Remsen in the chair.
The Past and the Future of the Scientific Association, by IRA REMSEN.

December 20.—One hundred and seventeenth regular meeting. Professor Remsen in the chair.
The Origin of Modern Learned Associations, by D. C. GILMAN.
Notes from the "Philosophia Naturalis of Phocylides," by C. W. JOHNSON.
Recent Observations of the Planet Mars, by C. L. POOR.

Philological Association.

October 19, 1894.—One hundred and thirty-sixth regular meeting. Professor Gildersleeve in the chair. Seventy members present.

Papers read:
The Awntyrs of Arthure, by W. H. BROWNE.
On the Etymology of the Term Ṡ^{e}vâ; On the Use of the Imperative in the Protasis of a Conditional Sentence; by C. LEVIAS.

November 16.—One hundred and thirty-seventh regular meeting. Professor Gildersleeve in the chair. Sixty members present.

Papers read:
Some Features of French Influence in Middle English, by F. H. SYKES.
Grammatical and Etymological Notes, by M. BLOOMFIELD.

December 21.—One hundred and thirty-eighth regular meeting. Professor Gildersleeve in the chair. Thirty-four members present.

Papers read:
On a Literary Judgment of Fronto, by M. WARREN.
Aristotle's Twelve Λύσεις or Poetic προβλήματα in the Light of the Homeric Scholia, by A. M. CARROLL.

Historical and Political Science Association.

October 19.—Kidd's Social Evolution: a review, by JOHN HAYNES.
A Visit to a Carmelite Monastery, by H. B. ADAMS.

November 16.—James Anthony Froude, by J. C. BALLAGH.
The Last Provincial Governor of Maryland, by B. C. STEINER.

December 7.—History of Industrial Arbitration, by E. R. L. GOULD.

December 21.—Historical Work of Herbert Tuttle, by H. B. ADAMS.

Physical Seminary.

The Physical Seminary has met regularly on Saturday mornings for the study and discussion of special topics in electro-chemistry, using Ostwald's large treatise as the basis.

Mathematical Seminary.

Directed by Professor CRAIG.

October Meetings.—In charge of Mr. W. W. LANDIS.

October 12.—On Linear Substitutions, by W. H. MALTBIE.

October 19.—On Linear Transformations of Modulus Unity, by T. H. TALIAFERRO.

October 26.—On Linear Transformations of Modulus Unity, continued, by T. H. TALIAFERRO.

November Meetings.—In charge of Mr. T. H. TALIAFERRO.

November 2.—Some Elementary Theorems on Connectivity of Surfaces, by W. W. LANDIS.

November 9.—Analysis Situs of One Dimension, by J. EIESLAND.

November 16.—Analysis Situs of One Dimension, continued, by J. EIESLAND.

November 23.—The Generation of Plane Curves by a Rolling Motion, by RENÉ DE SAUSSURE.

December Meetings.—In charge of Mr. C. R. DUVALL.

December 7.—The Generation of Twisted Curves by a Rolling Motion, by RENÉ DE SAUSSURE.

December 14.—On Developable Surfaces, by N. A. PATTILLO.

Naturalists' Field Club.

October 9.—Election of Officers.
President: BASIL SOLLERS; *Vice-President:* B. W. BARTON; *Secretary:* C. E. WATERS; *Secretary Botanical Section:* J. P. LOTSY; *Secretary Zoölogical Section:* C. P. SIGERFOOS.
The Winter Buds of Water-plants, by J. P. LOTSY.
Observations on the Development and Habits of a Young Fox, by B. W. BARTON.
Notes on Birds and Unios, by GEORGE H. GRAY.

November 13.
Notes on Fungi, etc., by J. E. HUMPHREY.
Notes on a New Fern, by J. H. BRUMMELL.
Notes on Some New Ferns, etc., and Late Blooming Plants, by C. E. WATERS.

December 11.
Notes on Cray-fish, by E. A. ANDREWS.
A New Analytical Key for Ferns, Based on Stipes, by C. E. WATERS.

January 8, 1895.
Migrations of Birds, by GEORGE H. GRAY, C. B. WILSON, B. W. BARTON.

Young Men's Christian Association.

October 20, 1894.—Reception to Professor William M. Ramsay of the University of Aberdeen, Levering Lecturer for 1894–95.

November 13.—Union Day of Prayer service for the students of all professional schools in the city. Professor H. A. KELLY of the Johns Hopkins Hospital and Rev. M. D. BABCOCK made addresses.

November 24.—Conference of Committees and association workers at the home of Dr. James Carey Thomas, to meet Mr. John R. Mott of the International Committee, and Mr. F. D. Brockman, College Secretary for the Southern States.

November 27.—Meeting in the interest of Bible Study. Address by Mr. JOHN R. MOTT, College Secretary of the International Committee.

November 27.—Association founded at the Johns Hopkins University Medical School.

December 7.—Meeting in the interest of Bible Study. Discussional classes formed.

December 17.—Meeting addressed by Mr. F. W. LANG, State Secretary.

PUBLIC MEETINGS AND SOCIAL ASSEMBLIES.

Held in the University buildings, from October 1, 1894, to January 15, 1895.

Opening Assembly of the University, October 8 [McCoy Hall].

Reception of the American Bankers' Association by the Bankers of Baltimore, October 11 [McCoy Hall].

Visits to McCoy Hall,—the Baltimore City College, October 12; the Woman's College of Baltimore, October 19; Mrs. Cary's school, November 2.

Reception in honor of Professor W. M. Ramsay, the Levering Lecturer, by the Young Men's Christian Association of the University, October 20 [Levering Hall].

Annual Meeting of the Charity Organization Society, November 12 [Levering Hall].

Annual Meeting of the Hospital Saturday and Sunday Association, November 19 [Levering Hall].

Annual Address and Social Assembly of the Presbyterian Association of Baltimore, November 26 [McCoy and Levering Halls].

Annual Convention of the Association of Colleges and Preparatory Schools of the Middle States and Maryland, November 30 and December 1 [Levering Hall].

Reception of the Association of Colleges and Preparatory Schools by the University, November 30 [McCoy Hall].

Dance of the Matriculate Society of the University, December 7 [McCoy Hall].

Meeting of citizens of Baltimore with respect to the recent sufferings in Armenia, December 10 [Levering Hall].

Meeting in behalf of the "Industrial House of the Ladies' Relief Association" of Baltimore, December 14 [Levering Hall].

Reception in honor of Professor Rhys-Davids, by the Graduate Students' Association, December 19; also a reception by the same body, November 10 [Levering Hall].

Annual Meeting of the Geological Society of America, December 27, 28, and 29 [Geological Laboratory].

Annual Meeting of the American Society of Naturalists, December 27 and 28 [Physical Laboratory].

Annual Meeting of the American Morphological Society, December 27 and 28 [Chemical Laboratory].

Annual Meeting of the American Physiological Society, December 27 and 28 [Biological Laboratory].

Reception of the four societies above named, by the University, December 27 [McCoy Hall].

Meeting of the "Friendly Visitors" of the Charity Organization Society, January 15 [Levering Hall].

AMERICAN JOURNAL OF MATHEMATICS.

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CHESSIN, A. Summation of Logarithmic and Exponential Series; Note on the General Solution of Bessel's Equation; Corrections.

CHREE, C. Isotropic Elastic Solids of nearly Spherical Form.

CRAIG, T. A Class of Uniform Transcendental Functions.

FRANKLIN, F. Note on Induced Linear Substitutions.

GOURSAT, E. Sur la transformation des courbes algébriques.

HUMBERT, GEORGES. Sur les surfaces de Kummer elliptiques.

MANNING, HENRY P. On the Order of Terms in a Semi-Convergent Series.

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PICARD, EMILE. Sur l'inversion des intégrales de fonctions à multiplicateurs.

STUDY, E. On the Addition Theorems of Jacobi and Weierstrass.

TABER, HENRY. On Orthogonal Substitutions that can be expressed as a Function of a Single Alternate (or Skew Symmetric) Linear Substitution.

VAN VLECK, EDWARD B. Zur Kettenbruchentwickelung hyperelliptischer und ähnlicher Integrale.

OBITUARY.

Mr. HENRY E. EBELING, of Baltimore, died January 10, 1895, at the age of 28 years. Mr. Ebeling was a graduate of the Gettysburg Theological Seminary in 1888, but had been engaged in teaching in Baltimore and elsewhere for a number of years. In October, 1893, he entered the Johns Hopkins University for advanced work in German. Since the beginning of the current session he had conducted a class for German Conversation, and recently he was appointed to a University Scholarship.

Mr. WILLIAM KNOWER, of Baltimore, died in Denver, Colo., December 27, 1894, aged 24 years. Mr. Knower received the degree of Bachelor of Arts of this University in June, 1891. Two years later he graduated from the Law School of the University of Maryland and practiced law until his health failed in the summer of 1894.

Mr. THOMAS WHITRIDGE, of Baltimore, died suddenly January 15, 1895, at the age of 27 years. He was a special student of History and English in the Johns Hopkins University during the year 1887–88, since which time he had been engaged in mercantile pursuits in Baltimore.

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